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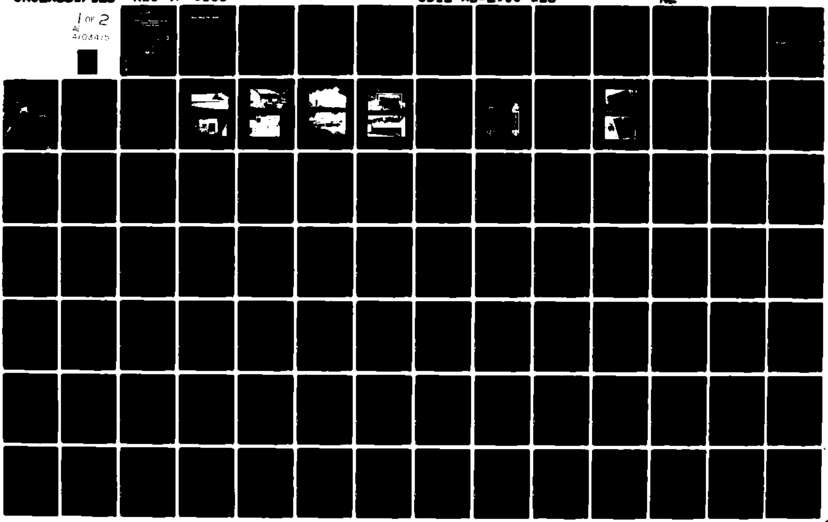

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Summary of Worldwide Thermal Exposure Incidental to Enclosed Storage

by
Carol Robertson
Howard C. Schafer
Range Department

APRIL 1981

NAVAL WEAPONS CENTER
CHINA LAKE, CALIFORNIA 93555

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Naval Weapons Center
AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

FOREWORD

This report presents and discusses the implication of thermal data, collected over a period of more than a dozen years, from enclosed storage facilities located worldwide. The effort described herein is only one segment of a program being pursued by the Naval Weapons Center (NWC), China Lake, California, and supported by the Naval Air Systems Command (AirTask A03W3300/008B/F31300000) aimed at defining the military environment as it pertains to air-launched tactical weapons.

The primary purpose of this report is the dissemination of the data in a form and format that can be readily used by design engineers in the United States and the free world. Secondarily, with the concurrence of NWC and Professor Daniel Stubbs, Ph.D., of the California Polytechnic State University (CPSU), San Luis Obispo, California, this report serves the major author (Carol Robertson) as a senior project report for the Computer Science Department at CPSU.

Approved by
C. L. SCHANIEL, *Head*
Ordnance Systems Department
8 April 1981

Under authority of
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(U) *Summary of Worldwide Thermal Exposure Incidental to Enclosed Storage*, by Carol Robertson and Howard C. Schafer. China Lake, Calif., Naval Weapons Center, April 1981, 108 pp. (NWC TP 6168, publication UNCLASSIFIED.)

(U) Environmental temperature criteria are a major controlling factor in the design of all types of military materiel. A program was therefore undertaken to investigate the actual thermal environment of Department of Defense materiel to determine realistic limitations of thermal exposure. This report contains a detailed analysis of actual field measured data from a representative sample of 47 storage sites located throughout the free world. It also serves as a summary report on the detailed analysis of all the storage depots in the U.S. Navy system as well as selected non-Navy depots (NWC TP 4143, Parts 1–6). Analysis of these data indicates that the high and low temperatures specified in military standards have never actually been encountered during the storage event of the materiel factory-to-use sequence.

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Tables:

INTRODUCTION

Environmental temperature criteria are a major controlling factor in the design of all types of ordnance and military materiel. However, the accepted temperature criteria, as set forth in the environmental sections of military specifications, may be such that ordnance actually meeting the needs of our military services could fail over-strenuous qualification requirements. Accurate knowledge of the thermodynamic interplay between the atmospheric temperature and the ordnance hardware temperature would permit more realistic design criteria to be assigned. Therefore, an investigation of the actual temperature environment of Department of Defense materiel was undertaken to determine realistic limitations of thermal exposure. The objective was to either (1) authenticate the thermal criteria for covered storage currently contained in military specifications, or (2) provide more realistic criteria for incorporation into these specifications.

It has been postulated[1] that the normal tactical propulsion system will spend approximately 85% of its life in covered storage. The importance of the definition of magazine storage therefore must not be overlooked. It must be remembered that the life of any ordnance, most other explosive devices, and the majority of expendable materiel items is spent in some type of secure or covered storage. If this is true, then even though the thermal exposure of the materiel is somewhat benign in covered storage, it will make up the major portion of the total thermal exposure to which the item will be exposed and on which the major degradation of any stable chemical could be based.

The definition of the environment in covered exposure is also important for other reasons, the most important being that any materiel must successfully survive the storage event in its factory-to-use sequence with minimal to no degradation. If the item cannot perform its designed function following storage, then in essence, the taxpayer and the service user are both being shortchanged.

This report provides a follow-up and a more complete overview of temperatures in storage magazines located worldwide. The data presented herein supports and updates information in a previously published series

[1] Naval Weapons Center. *Environmental Criteria Determination for Air-Launched Tactical Propulsion Systems*, by Howard C. Schafer. China Lake, CA, NWC, July 1968. (NWC TP 4464, Parts 1, 2, and 3, publication UNCLASSIFIED.)

of reports which indicated the range of temperatures to which ordnance and materiel are exposed in storage magazines.[2-7] This previously published data (see footnotes 2-7) indicated that the high (165°F) and low (-65°F) temperatures specified in the military standards were never measured and are not even close to being realistic during the materiels' sojourn in the covered storage event of the factory-to-use sequence.

The magnitude of the differences between the temperature of the air inside the magazine, the temperature of the ordnance or materiel located in the structure, and the mean daily air temperature is hard to compare. A major roadblock to a proper collection of data to make a statistical comparison is safety; placing instrumentation inside an explosive magazine could be hazardous. Also, there usually is no electric power anywhere near such storage structures with which to run instrumentation. These difficulties were surmounted, however, and a special dispensation was granted so that a sample of such data could be obtained. These data have been published[8] not as a conclusive expression of the correlation, but only as a first glimpse into it.

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[2] Naval Ordnance Test Station. *Storage Temperature of Explosive Hazard Magazines. Part 1. American Desert,* by J. S. Kurotori and H. C. Schafer. China Lake, CA, NOTS, November 1966. (NOTS TP 4143, Part 1, publication UNCLASSIFIED.)

[3] ------. *Storage Temperature of Explosive Hazard Magazines. Part 2. Western Pacific,* by J. S. Kurotori and H. C. Schafer. China Lake, CA, NOTS, June 1967. (NOTS TP 4143, Part 2, publication UNCLASSIFIED.)

[4] ------. *Storage Temperature of Explosive Hazard Magazines. Part 3. Okinawa and Japan,* by J. S. Kurotori and H. C. Schafer. China Lake, CA, NOTS, June 1967. (NOTS TP 4143, Part 3, publication UNCLASSIFIED.)

[5] Naval Weapons Center. *Storage Temperature of Explosive Hazard Magazines. Part 4. Cold Extremes,* by J. S. Kurotori and H. C. Schafer. China Lake, CA, NWC, May 1968. (NWC TP 4143, Part 4, publication UNCLASSIFIED.)

[6] ------. *Storage Temperature of Explosive Hazard Magazines. Part 5. Caribbean and Mid-Atlantic,* by J. S. Kurotori and H. C. Schafer. China Lake, CA, NWC, March 1969. (NWC TP 4143, Part 5, publication UNCLASSIFIED.)

[7] ------. *Storage Temperature of Explosive Hazard Magazines. Part 6. Continental United States,* by J. S. Kurotori, R. Massaro, and H. C. Schafer. China Lake, CA, NWC, November 1969. (NWC TP 4143, Part 6, publication UNCLASSIFIED.)

[8] ------. *Summary of Selected Worldwide Temperatures in Explosive Hazard Magazines,* by I. S. Kurotori and H. C. Schafer. China Lake, CA, NWC, February 1972. (NWC TP 5174, publication UNCLASSIFIED.)

This report is based on storage data of explosive ordnance from forty-seven locations throughout the world; thirty-six locations from the previously published series of reports (see footnotes 2-7), seven locations from Europe (Cartagena, Spain; Messina, Sicily; Machrihanish, Scotland; Rota, Spain; Soudha Bay, Crete; Welford, England; and Wiesau, Germany), and four locations from Australia. (The European and Australian data contained in this report have not been previously published.) Of these forty-seven locations, twenty-eight (twenty-two from the NWC TP 4143 series, footnotes 2-7, two from the European area and four from Australia) were randomly selected in such a way as to represent the climatic zones used for comparison purposes in this report.

The data reported herein are comprised of the measured air temperature inside the described structures only. In most cases, any ordnance stored in these structures cannot be expected to thermally follow the variations in temperature of the enclosed air. The difference in mass between the air and ordnance can be expected to negate this. Therefore, any temperature herein reported can be treated as "conservative" for the temperature of the ordnance stored in these explosive hazard magazines. (In general, the temperature of the ordnance hardware will tend to follow the mean daily air temperature within the storage structure rather than the maximum and minimum recorded air temperatures.)

BACKGROUND

CLASSIFICATIONS OF CLIMATES

The surface of the world has been classified into a limited number of climatic zones which typify temperatures encountered worldwide. These zones were chosen to limit the amount of data handling per zone and yet not compromise the credibility of these data. It was concluded that the best approach for the purposes of this report would be the climate classifications set forth by W. Koppen[9]. Koppen classified the world into six major climatic zones: tropical rainy, dry, humid mesothermal, humid microthermal, polar, and undifferentiated highlands. These climatic zones and their characteristics can be briefly described as follows.

1. Tropical rainy climates: No cool season; mean temperature of coldest month above 64.4°F (18°C); 20% of land mass.

2. Dry climates: Arid or semi-arid; evaporation exceeds precipitation. The limits of the dry climates are determined not by the total annual precipitation, but by the amount of rainfall

[9] Thomas A. Blair. *Climatology*. New York Prentice Hall Inc., 1942. pp. 123.

in relation to the temperature and to the season in which the rain falls, since both temperature and the seasonal distribution of rain influence the soil moisture to plants; 32% of land mass.

3. Humid mesothermal climates: Rainy climates with mild winters; coldest month less than 64.4°F, but warmer than 26.6°F (-3°C); warmest month above 50°F (10°C); short winters, but ground may be frozen or snow-covered for a month or more; 14% of land mass.

4. Humid microthermal climates: Rainy climates with severe winters. Warmest month above 50°F; coldest month below 26.6°F; long winters; ground frozen for several months of the year; much of winter precipitation is found in snow; 22% of land mass.

5. Polar climates: No warm season; mean temperature of warmest month less than 50°F; 5% of land mass.

6. Undifferentiated highlands: High altitudes in middle or low latitudes; 7% of land mass.

These six broad divisions, as defined by Koppen, are subdivided into a large number of climatic types in accordance with temperature differences and variations in the amount and distribution of precipitation. However, the needs of this report *do not require* the use of more than the six basic divisions for a definitive comparison of magazine temperatures and climatology in general.

Using Koppen's classifications as a guideline, it was decided that further simplification can be made in reference to the polar and undifferentiated highlands. These climatic zones were not included in this report because:

1. Through knowledge of previous wars, it can be stated that storage depots are located in the same climatic zones as the majority of the world population. Though together polar and undifferentiated highlands constitute 12% of the land mass, the population in these areas constitutes less than 0.01% of the world population. Therefore, the probability that permanent storage depots would be constructed in these areas would be very small.

2. Storage depots are located in areas where transportation is readily available, generally near deep water anchorages or major rail lines. In polar and undifferentiated highlands, there is no major rail transportation and ships may access these areas, at most, 6 months out of the year.

Other methods to further reduce the number of climatic zones to give a more general application for the world were considered and subsequently rejected because each climatic zone differs significantly from the other. However, since materiel is designed for worldwide use, an overall approximation must be attempted. (If materiel is to be designed for a specific geographic location, do not use any of the curves in the following sections of this report other than the one that covers that parochial location.)

Figure 1 and Table 1 denote the forty-seven locations initially considered in this report. (More detailed information and data concerning all forty-seven locations may be obtained through the Naval Weapons Center, Code 6212, China Lake, CA.) Table 2 identifies, according to climatic zone, the twenty-eight locations for which data were reduced, tabulated and plotted.

PHYSICAL APPEARANCE OF MAGAZINES

Igloos

Igloos (Figure 2) are earth-covered storage structures usually with 2 feet of compacted earth covering them. Many have concrete floors and walls (rear and front). Some igloos have corrugated steel arches, concrete floors and metal fronts. The thermal data collected from these type facilities often are not representative of the enclosed materiel because the metal front closures offer very little thermal protection, and the thermometers are mounted near the door (see Figure 3). Another igloo type is the 18-foot-long Quonset hut type tunnel, approximately 7 feet high with corrugated steel arches and concrete floors (see Figure 4). Whatever the internal design and construction, all igloos are normally covered with 2 feet of compacted earth as required in OP-5.

Above-Ground Storehouses

The above-ground storehouses have no earth covering to protect against the ambient temperature extremes. Ready service lockers (see Figure 5), outside storage (tarpaulin, sheds, etc., -- see Figures 6 and 7), and temporary shelters are examples of this type of storage (see Figure 8). Concrete construction with multiple cubicles (see Figure 9) may also be classified as above-ground storehouses. Generally, little if any live ordnance is habitually stored in any of the above-ground storehouses for indefinite periods of time, though inert materiel are so stored. Also, even under the most pressing wartime situation, the first live ordnance so stored will be the less expensive bombs and gun projectiles. The sophisticated ordnance, which is usually very expensive, will be given

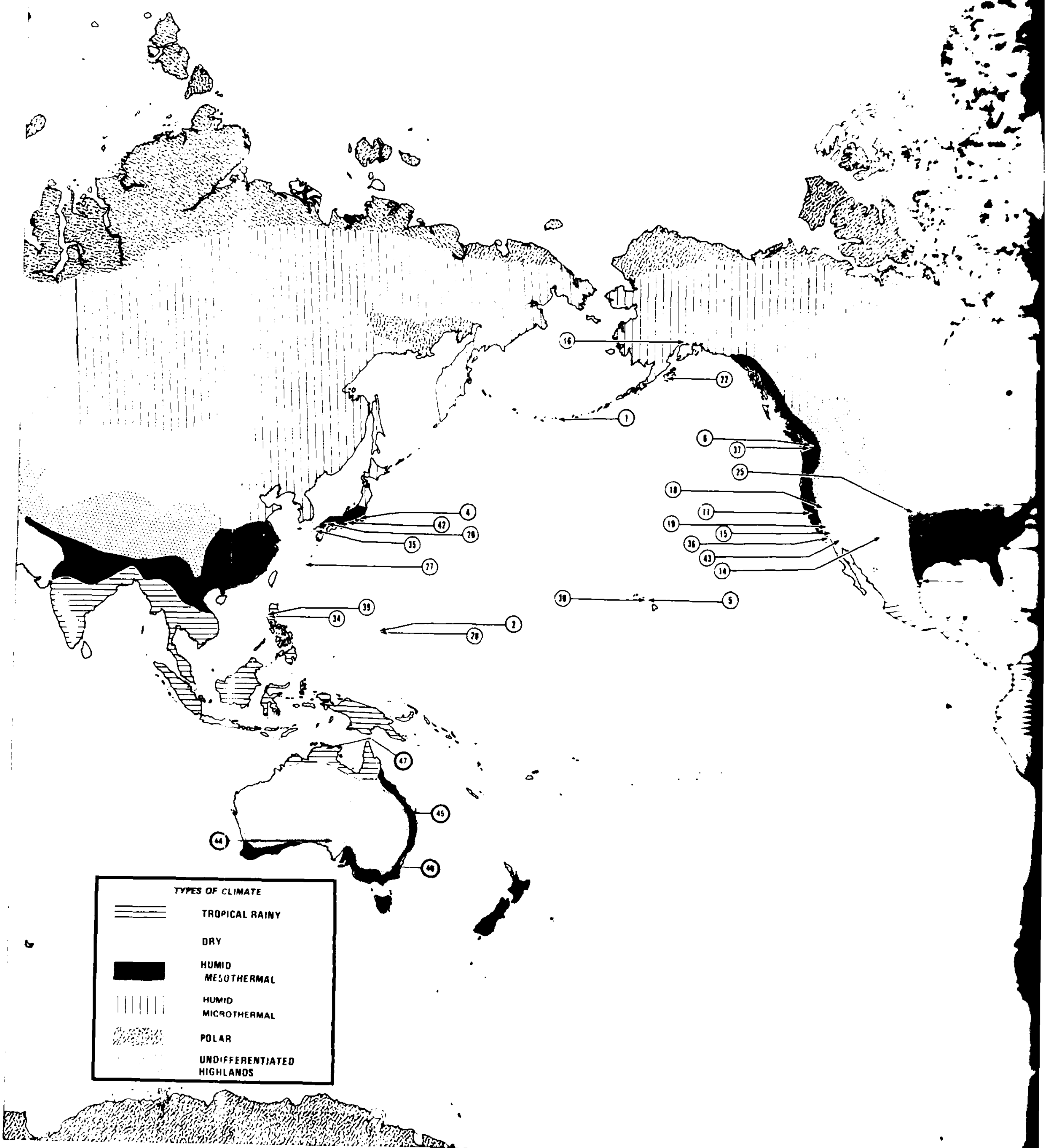

FIGURE 1. World Map of Storage Lo

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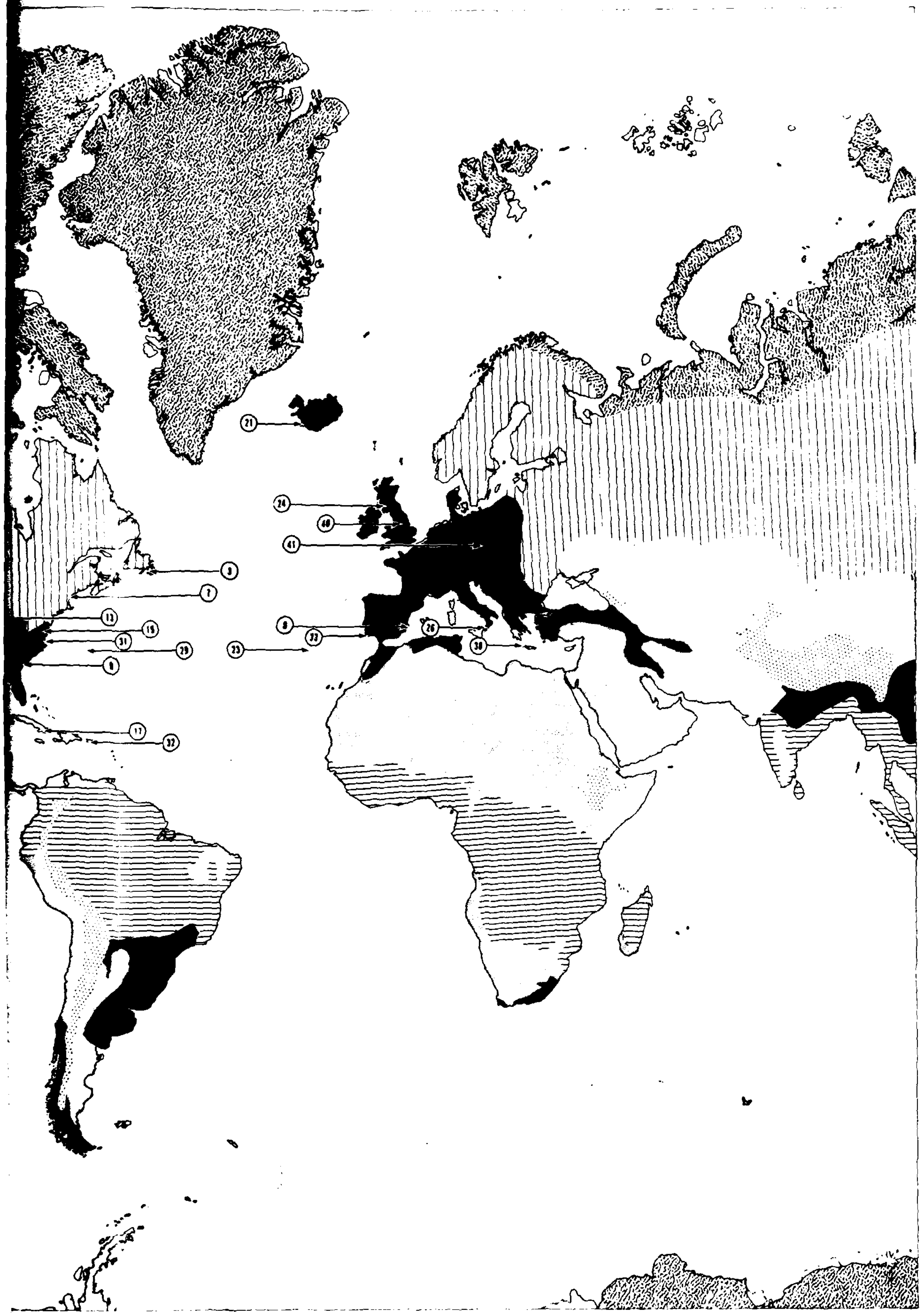

Locations and Climatic Zones.

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TABLE 1. List of Forty-seven Storage Locations.

1. Adak, Alaska
2. Agana, Guam
3. Argentia, Newfoundland
4. Atsugi, Japan
5. Barbers Point, Hawaii
6. Bremerton, Washington
7. Brunswick, Maine
8. Cartagena, Spain
9. Charleston, South Carolina
10. China Lake, California
11. Concord, California
12. Corpus Christi, Texas
13. Crane, Indiana
14. Dallas, Texas
15. El Toro, California
16. Fort Richardson, Alaska
17. Guantanamo Bay, Cuba
18. Hawthorne, Nevada
19. Indian Head, Maryland
20. Iwakuni, Japan
21. Keflavik, Iceland
22. Kodiak, Alaska
23. Lajes, Azores
24. Machrihanish, Scotland
25. McAlester, Oklahoma
26. Messina, Sicily
27. Naha, Okinawa
28. Naval Magazines, Guam
29. Naval Station, Bermuda
30. Oahu, Hawaii
31. Portsmouth, Virginia
32. Roosevelt Roads, Puerto Rico
33. Rota, Spain
34. Sangley Point, Republic of the Philippines
35. Sasebo, Japan
36. Seal Beach, California
37. Seattle, Washington
38. Soudha Bay, Crete
39. Subic Bay, Republic of the Philippines
40. Welford, England
41. Wiesau, Germany
42. Yokosuka, Japan
43. Yuma, Arizona
44. Kingswood, Australia
45. Amberly, Australia
46. East Sale, Australia
47. Darwin, Australia

TABLE 2. List of Twenty-eight Storage Locations.

	Tropical climates
2.	Agana, Guam
17.	Guantanamo Bay, Cuba
30.	Oahu, Hawaii
32.	Roosevelt Roads, Puerto Rico
39.	Subic Bay, Republic of the Phillippines
47.	Darwin, Australia
	Dry climates
10.	China Lake, California
14.	Dallas, Texas
18.	Hawthorne, Nevada
43.	Yuma, Arizona
44.	Kingswood, Australia
45.	East Sale, Australia
	Humid mesothermal climates
4.	Atsugi, Japan
9.	Charleston, South Carolina
12.	Corpus Christi, Texas
21.	Keflavik, Iceland
25.	McAlester, Oklahoma
26.	Messina, Sicily
29.	Naval Station, Bermuda
36.	Seal Beach, California
37.	Seattle, Washington
41.	Wiesau, Germany
45.	Amberly, Australia
	Humid microthermal climates
1.	Adak, Alaska
3.	Argentia, Newfoundland
7.	Brunswick, Maine
13.	Crane, Indiana
22.	Kodiak, Alaska
	Polar climates
No data available	
	Undifferentiated highlands
No data available	

FIGURE 2. Igloo Magazine With Concrete Floor and Concrete Walls.

FIGURE 3. Igloo Magazine With Metal Front Closures.

FIGURE 4. Igloo Magazine - Tunnel.

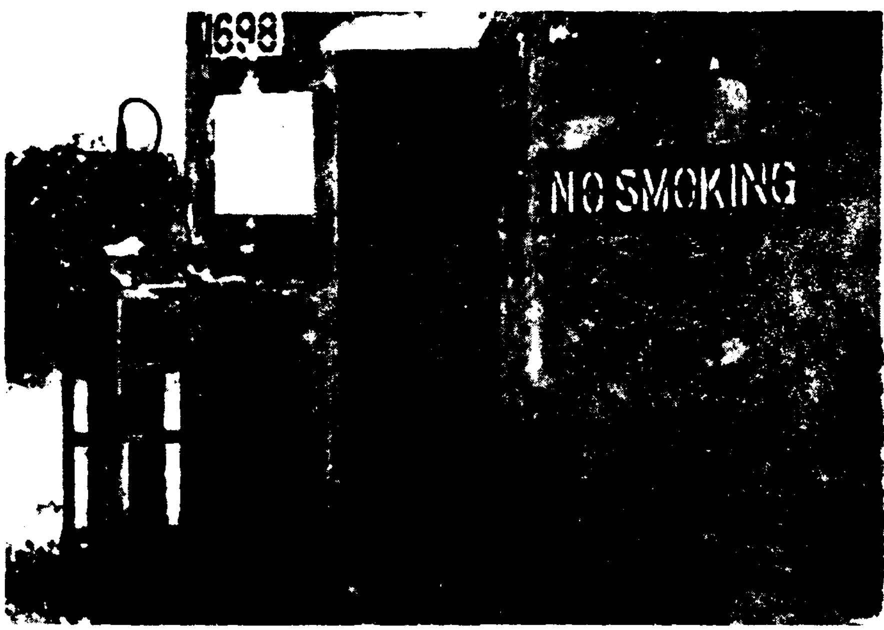

FIGURE 5. Above-Ground Storehouse -- Ready Service Locker.

FIGURE 6. Above-Ground Storehouse -- Outside Storage, Tarpaulin.

FIGURE 7. Above-Ground Storehouse -- Outside Storage, Shed.

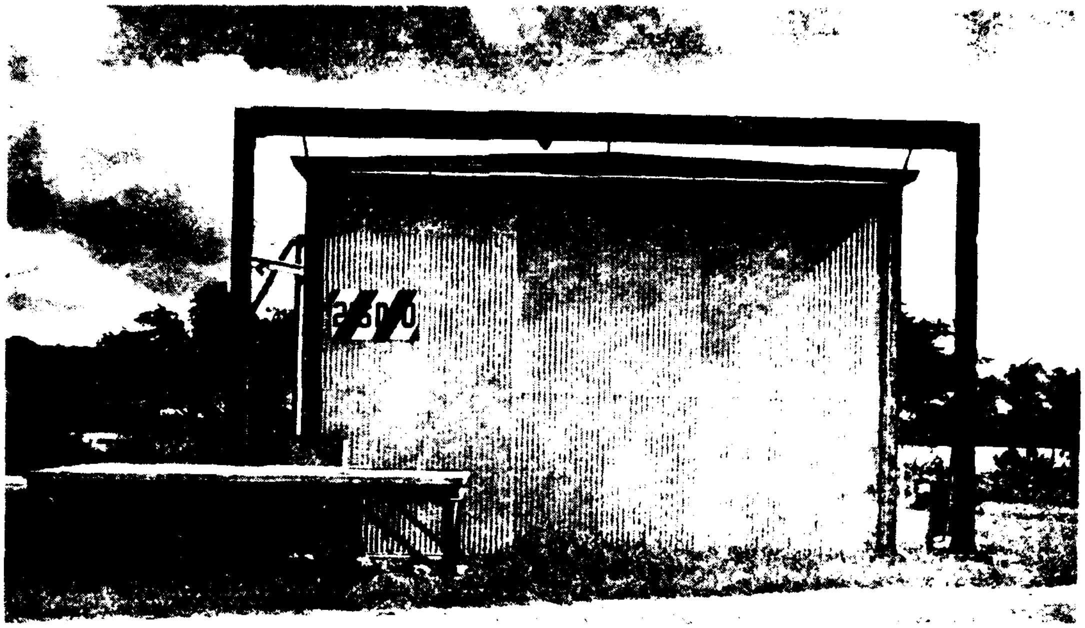

FIGURE 8. Above-Ground Storehouse -- Temporary Storage.

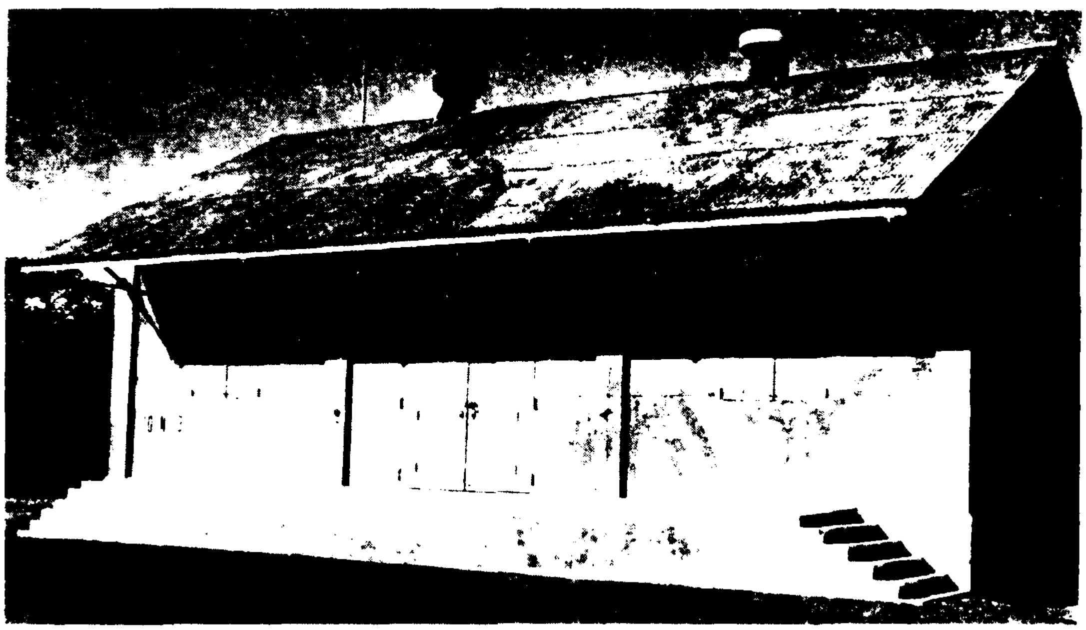

FIGURE 9. Above-Ground Storehouse -- Concrete Construction With Multiple Cubicles.

preferential treatment, i.e., storage in any available igloos. A detailed analysis of the use of facilities at the Naval Magazine, Subic Bay, between 1963 and 1975 will verify the above rules of thumb for materiel storage during a wartime situation.

Information excerpted from the Navy's document covering all subjects related to storage of explosives ashore can be found in Appendix A. This appendix presents the OP-5 explanations for standard sizes and optimal loading for the various storehouses and explosive hazard magazines.

DATA BASE

The total data base available for this report is comprised of data from explosive hazard magazines and above-ground storehouses collected from 1955 through 1978. The major data concentration was from the last half of the 1960s. A count of individual data points was stopped at 3 million. The total volume of logbooks and temperature record sheets (in excess of 150 ft^3) has since been used as the measure of data available. Obviously the effort necessary to sift through this massive volume of data would entail an excessive expenditure of manpower and money; therefore, a sampling scheme seemed a more appropriate method of deriving useful information.

Work done by Brigham Young University for NWC indicated that a fair amount of accuracy could be retained with only a 10% sample of continuously recorded temperature data, when it is placed in a cumulative probability versus temperature format. In fact, in NWC TP 4834, Part 3, it is shown that the use of only 1% of the data is conducive to only a 5% error when large amounts of cyclic data are available.[10] Based on this experience, it was deemed reasonable to apply this sampling process, in a much modified manner, to these data. It was somewhat arbitrarily decided by the authors to use 2 years of data from each of the representative depot locations. Thus, the overall job was reduced to manageable proportions, yet the statistical accuracy would not be unduly compromised. Even so, the data necessary to carry out even this much-abridged program totaled in excess of 700,000 maximum and minimum temperature data points.

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[10] Naval Weapons Center. *Evolution of the NWC Thermal Standard. Part 3. Application and Evaluation of the Thermal Standard in the Field*, by Dr. Richard D. Ulrich, Brigham Young University and Howard Schafer, Naval Weapons Center. China Lake, CA, NWC, May 1977. (NWC TP 4834, Part 3, publication UNCLASSIFIED.

INSTRUMENTATION

The magazine temperature data were obtained through the use of "horseshoe" maximum and minimum mercury thermometers (see Figure 10). These thermometers are equipped with steel "tattletale" devices that float on the mercury and remain at the highest and lowest temperature positions reached during the measurement period. The ordnancemen reset the tattletales with a magnet after reading the indicated maximum and minimum temperature for the measurement period. The manufacturers of

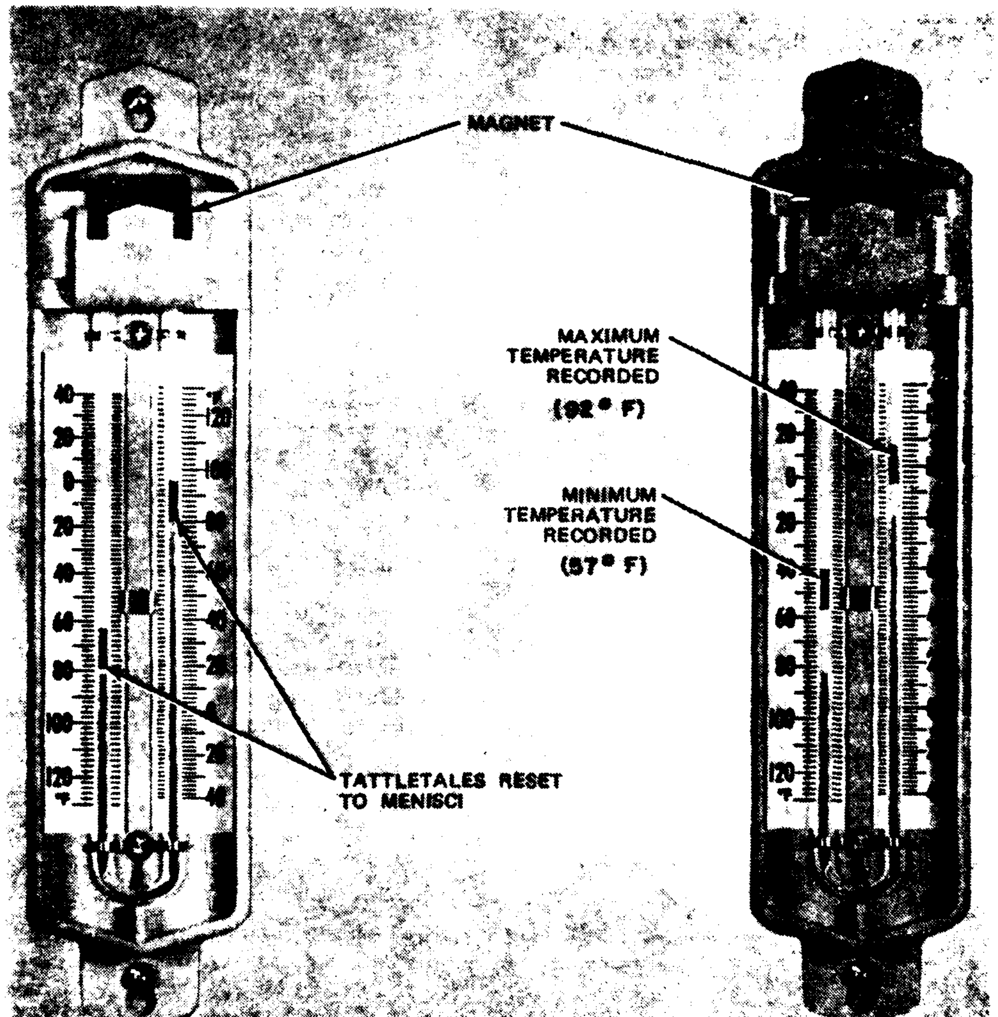

FIGURE 10. Horseshoe Thermometer.

the thermometers (Taylor, Weksler, and Moeller) warrant that the temperature readings are accurate to within 2°F at time of delivery to the Navy. These thermometers are mounted on the inside forward face of the front or back wall of the explosive hazard magazines at about eye level (standard procedure).

The nonstandard magazines may not allow the placement of the thermometers at the usual locations within the magazines. For example, in above-ground corrugated steel storehouses, the temperature would be hotter if the thermometer were placed high above the floor. If the location of the thermometer changes in the storehouse, an error is induced in the statistical treatment of the "nonstandard" data because of the different position of the thermal gradient in the quiescent air being measured. In many cases, the thermometers have been observed to be mounted on boards and situated for convenience even in "standard" type magazines.

METHODS OF DATA RETRIEVAL AND REDUCTION

All available raw data from the specified forty-seven locations were collected and sent to NWC. These raw data were received in various forms, i.e., temperature logbooks (Figure 11), individual monthly magazine temperature record cards (Figure 12), or individual temperature record sheets gathered together in an envelope and submitted on a monthly basis. These records identified the month, day, and year the temperatures were recorded as well as the type of magazine. The storage depot was identified by the postmark and return address on the envelope.

These raw data were keypunched, reduced, tabulated and plotted to yield meaningful statistics and significant points of interest for igloos and above-ground storehouses of each storage location and groups of storage locations according to climatic zones.

The following points concern the variance of individual data that should be taken into consideration.

1. The time intervals at which temperature readings were taken were not equal. The temperatures in some magazines were recorded daily, weekly, biweekly, or monthly, or less frequently, depending on the materiel and procedures used at each facility. The maximum and minimum temperature readings were those encountered within the magazine during those intervals of time. This, of course, biases the results toward the extreme, since a high or low temperature for 1 day may be the recorded temperature for that magazine for a 1-week or greater period instead of for that specific day.

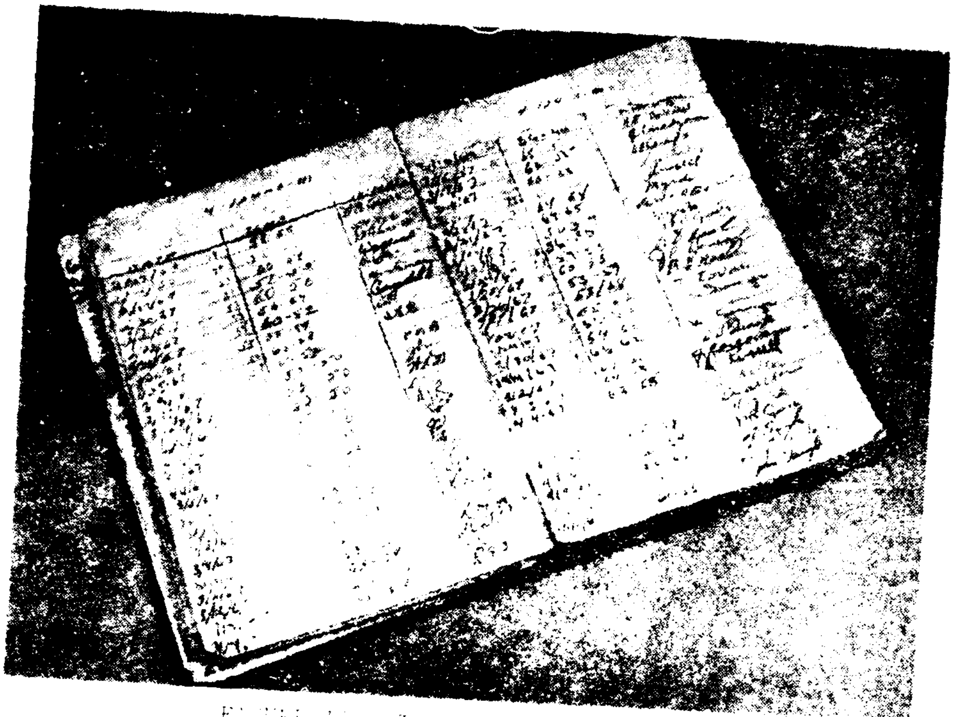

FIGURE 11. Temperature Log Book.

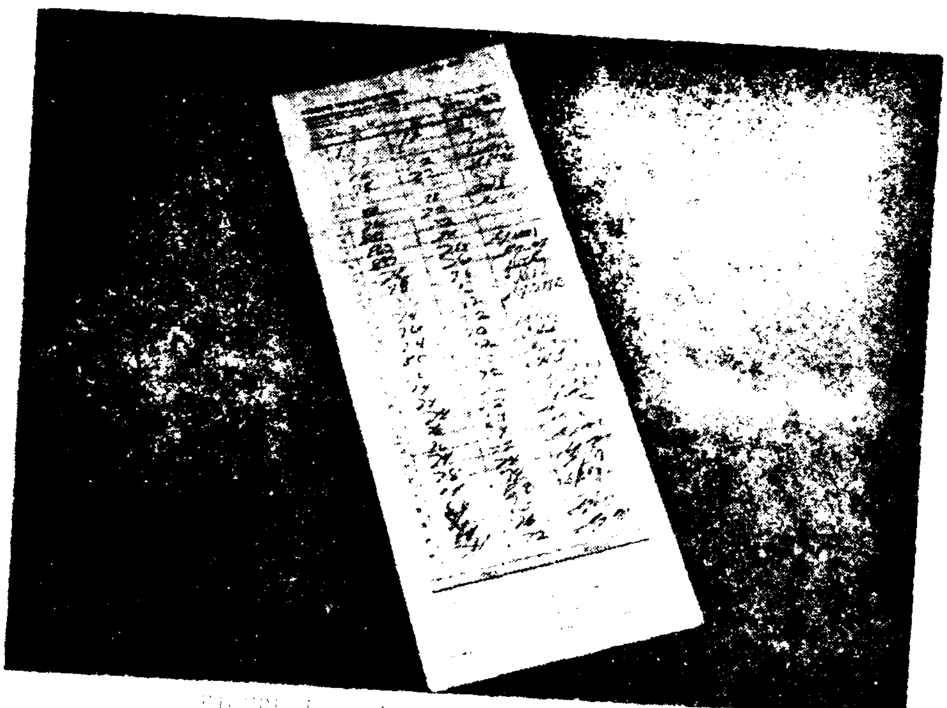

FIGURE 1[illegible]. Temperature Record Card.

2. The amount of ammunition in the storage magazines is not always constant. The absorption of heat by the ammunition (dependent on the quantity of materiel) within the magazine could account for differences in temperature readings because the mass of the air in an empty structure will thermally follow any change much quicker than would a full load of materiel.

3. The frequency at which the magazine doors are opened will also influence the temperature readings.

4. In some cases thermometer calibration errors were found. These usually could be spotted in a comparison of like data from the same station. However, it must be assumed that some of these erroneous data slipped through the screening process.

5. Thermometers are not always read properly. On rare occasions, an inexperienced person will read the top of the metal "tattletale" instead of the bottom. This will lead to a nominal 20°F error toward the extreme. Care has been taken to eliminate these errors during data screening by the comparison method. However, no control could be exercised by NWC personnel on the data gathering.

The usual interest in any data gathering and ordering effort is in the extreme or rare event, not the mean or commonplace. All the previously stated error possibilities, with the possible exception of 5, will lead to "extreme" errors. It can, therefore, be safely assumed that not all of the data-in-error was culled prior to workup. Therefore, the data presentations in the *Results* section can be considered "conservative". Appendix B details the data handling from raw data to the finished graphs. Included in this appendix are descriptions and outputs of the computer programs used to determine the final output. A brief description of the statistical implications are also provided in this appendix.

RESULTS

In excess of 700,000 maximum and minimum temperature data points, representing nominally 24 hours per day or less, per two data points, were collected during this investigation. These data represent 13 igloo years from 1955 through 1968 and 12 above-ground storehouse years from 1956 through 1968. Appendix C is a compilation of the individual cumulative probability displays for igloos and above-ground storehouses. The following discussions of the specific type of storage (igloo and above-ground storehouses) and the combination of the two indicate that the thermal environment of storage magazines is truly moderate.

The discussions which follow are based on data from the selected twenty-four locations (Table 2). These locations are discussed according to their climatic zones and each zone is discussed according to the type of storage.

IGLOOS (earth-covered explosive hazard magazines)

Figures 13 through 16 are the cumulative probability displays for the tropical rainy, dry, humid mesothermal, and humid microthermal climates. Figure 17 is the cumulative probability display for all climates combined. The maximum reported temperature for Figure 17 is 105°F, while the minimum reported temperature is 20°F. The quantification of the maximum temperature is 0.9999. This is defined to mean that 99.99% of the time the magazine temperature is expected to be 105°F or less; conversely, 105°F or more will almost never be expected. The quantification of the minimum temperature is 0.0009. This is defined to mean that 0.09% of the time the magazine temperature is expected to be 20°F or colder. The quantification value of 0.09% is roughly equivalent to experiencing a minimum temperature of 20°F for a total of approximately 1 day in each 3-year period.

Most of the tropical rainy data (Figure 13) was obtained between the Tropic of Cancer and the equator. The maximum reported temperature is 108°F, while the minimum reported temperature is 68°F. For information regarding the quantification analysis, refer to Table 3.

TABLE 3. Quantification Analysis -- Igloos.

Climatic zone	Temperature, °F		Quantification		Single day frequency of occurrence, years	
	Max	Min	Max	Min	Max	Min
Tropical	108	68	1.0000	0.0012	(a)	2.28
Dry	105	40	0.9999	0.0006	27.7	4.56
Humid mesothermal	100	28	0.9997	0.0022	9.4	1.24
Humid microthermal	85	18	0.9996	0.0024	6.8	1.14
All climates	105	20	0.9999	0.0009	27.7	3.04

(a) Extremely rare.

The dry data (Figure 14) was obtained mostly in the United States. However, the information that is lacking from other dry locations worldwide has been shown to be similiar or closely related to the information obtained from our selected locations.[11-15] The maximum recorded temperature shown is 105°F, while the minimum recorded temperature is 40°F. Table 3 details the quantification analysis for this zone.

The humid mesothermal data (Figure 15) was obtained from various areas worldwide. The sharpness of the curve is due largely to the data encountered in the European location of Messina, Sicily (see Appendix C). All data from Messina was in Centigrade and, before reduction could be completed, that data had to be converted to Fahrenheit. Upon conversion, any significant digits were deleted, and only the integer value was maintained. Therefore, many measurements were computed as being equal and this equality would account for the almost vertical slope of this particular graph. The highest measured temperature obtained was 100°F, while the lowest measured temperature obtained was 28°F. For information detailing the quantification analysis, refer to Table 3.

The humid microthermal data (Figure 16) was obtained between 30 and 60 degrees longitude. The maximum reported temperature was 85°F, while the minimum reported temperature was 18°F. For information regarding the quantification anlaysis, refer to Table 3.

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[11] Headquarters Quartermaster Research and Development Command. *Analogs of Yuma Climate in the Middle East, Yuma Analogs No. 1*, Natick, MA, March 1954. (Report no. 7-83-03-002, publication UNCLASSIFIED.)

[12] Headquarters Quartermaster Research and Engineering Command, U.S. Army. *Analogs of Yuma Climate in Northeast Africa, Yuma Analogs No. 2*, by William C. Robison. Natick, MA, August 1954 (revised September 1957). (Report no. 7-83-03-008A and 7-83-01-005A, publication UNCLASSIFIED.)

[13] Headquarters Quartermaster Research and Development Command. *Analogs of Yuma Climate in South Centeral Asia, Yuma Analogs No. 4*, by William C. Robison and Arthur V. Dodd. Natick, MA, June 1975. (Report no. 7-83-03-008A, publication UNCLASSIFIED.)

[14] Headquarters Quartermaster Research and Engineering Command, U.S. Army. *Analogs of Yuma Climate in Soviet Middle Asia, Yuma Analogs No. 5*, by William C. Robison and Arthur V. Dodd. Natick, MA, September 1955 (reprinted May 1958). (Project Reference 7-83-01-001B, publication UNCLASSIFIED.)

[15] United States Army, Natick Laboratories. *Classification of World Desert Areas*, by George H. Howe, et al. Natick, MA, December 1968. (Technical Report 69-38-ES, publication UNCLASSIFIED.)

Keep in mind that the cumulative probability versus temperature display of data provides an immediate indication of the risk commensurate with the use of any temperature value. As a rule of thumb you are safe using any temperature for prediction purposes as long as the line in the figure is nearly horizontal. When the slope of the line approaches vertical, in general, it is not advisable to use these temperature values for design or test values. The reasoning behind these rules of thumb is that when the cumulative curve approaches horizontal you are in the range of the extreme or rare occurrence (there are next to no data); as a curve approaches vertical more and more data are represented and you are approaching the mean. Therefore, for conservative use, the one-sided Gaussian 3 sigma quantification values of 0.003 and 0.997 should usually be used for most "extreme" temperature values. In Figure 15 the 0.997 value is 100°F and the 0.003 value is 25°F.

Since Figure 17 is a composite of Figures 13 through 16, it may be of interest to examine the unique contributions to it from its component parts. The Figure 17 maximum and minimum temperature values will be the maximum and minimum values of the composite of Figures 13 through 16. It can be seen that the 112°F was contributed by Figure 13, originally derived from Guantanamo Bay, Cuba (see Appendix C). The minimum temperature of 20°F is derived from Figure 16 (the Brunswick, Maine data). The "flat spot" between 0.25 and 0.35 cumulative probabilities is a direct reflection of the Figure 15 "flat spot" and can be traced directly to the data from Messina, Sicily. Notice that the "flat spot" seems to diminish as more data are available. In the Messina plot it extended from 0.04 to 0.9 cumulative probability. When "diluted" by the other worldwide data for the Figure 17 display, it had been reduced to the 0.25 to 0.35 cumulative probabilities.

ABOVE-GROUND STOREHOUSES

Figures 18 through 21 are the cumulative probability displays of above-ground storehouses for each climatic zone. Figure 22 is the cumulative probability display of above-ground storehouses for all climates. The maximum reported temperature for Figure 22 is 119°F; the minimum recorded temperature is 5°F. The quantification of this maximum temperature is 0.9999. This means that 99.99% of the time the magazine temperature is expected to be 119°F or less. Conversely, only 0.01% of the time will a temperature of 119°F or more be expected. The quantification value of 99.99% is roughly equivalent to experiencing a maximum temperature of 119°F for a total of 1 day in each 27-year period. The quantification of the minimum temperature is 0.0006. This is defined to mean that 0.06% of the time the magazine temperature is expected to be 5°F or less. The quantification value of 0.06% is roughly equivalent to experiencing a minimum temperature of 0°F for a total of 1 day in each 13-year period.

Comparing the above-ground storehouses with the igloos, one will notice that, generally, there are consistent temperature differences between them. The amount of variation is because igloos protect materiel from the meteorological elements, regardless of the magazine display. Apparently any sort of covering will protect materiel from the solar radiation-induced extreme temperatures. Also, the 2 feet of compacted earth covering the igloos will time phase change the yearly maximum temperature inside the structure between 1 and 3 months behind the meteorological air temperature maximums (see footnote 10).

The tropical rainy zone (Figure 18) maximum and minimum reported temperatures are 100° and 60°F, respectively. In comparing igloos with above-ground storehouses for this climatic zone, one will notice that the maximum reported temperature for igloos is greater than that for above-ground storehouses. This, in reality, should be reversed (above-ground storehouse maximum temperatures should be greater than that of the igloos). The appearance of this maximum temperature (112°F for igloos) suggests that a temperature was measured out of normal context. The apparently erroneous data were obtained from Guantanamo Bay, Cuba (see Appendix C). This apparent error may be due to any of the previously explained reasons (see *Methods of Data Retrieval* and *Reduction*). A review of the data digital printout indicates that 107°F may be a more realistic value. Since the difference between 112°F and 107°F is in reality small, the 112°F value was retained herein.

The dry climate (Figure 19) maximum and minimum reported temperatures are 119° and 20°F, respectively. These temperatures differ significantly from the igloo maximum and minimum of 105° and 40°F. The differences are chiefly due to the fact that above-ground storehouses are more subject to the cold of winter, heat of summer, and solar radiation heat loads. However, even with these extreme temperatures, enclosed materiel temperatures are still relatively moderate when compared with those experienced in open field storage.[16-18] Table 4 details the quantification analysis for this zone.

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[16] Naval Weapons Center. *Measured Temperatures of Solid Rocket Motors Dump Stored in the Tropics and Desert. Part 1. Discussion and Results*, by Howard C. Schafer. China Lake, CA, NWC, November 1972. (NWC TP 5039, Part 1, publication UNCLASSIFIED.)

[17] ------. *Measured Temperatures of Solid Rocket Motor Dump Stored in the Tropics and Desert. Part 2. Data Sample*, by Howard C. Schafer. China Lake, CA, NWC, November 1972. (NWC TP 5039, Part 2, publication UNCLASSIFIED.)

[18] ------. *Measured Temperatures of Solid Rocket Motors Dump Stored in the Tropics and Desert, Part 3. Desert Storage*, by Howard C. Schafer China Lake, CA, NWC, May 1977. (NWC TP 5039, Part 3, publication UNCLASSIFIED.)

TABLE 4. Quantification Analysis -- Above-Ground Storehouses.

Climatic zone	Temperature, °F		Quantification		Single day frequency of occurrence, years	
	Max	Min	Max	Min	Max	Min
Tropical	100	60	0.9999	0.0012	27.7	2.28
Dry	119	20	0.9995	0.0008	5.4	3.42
Humid mesothermal	106	18	0.9998	0.0042	14.0	0.65
Humid microthermal	90	0	1.0000	0.0014	(a)	1.96
All climates	119	5	0.9999	0.0006	27.7	4.56

[a] Extremely rare.

The humid mesothermal climate (Figure 20) maximum and minimum measured temperatures are 106° and 18°F, respectively. These temperatures differ significantly from the igloo maximum and minimum of 100° and 28°F, respectively. These differences, again, are due largely to the type of covering the igloos provide. However, even with these differences, the temperatures are still relatively moderate. For information detailing the quantification analysis, refer to Table 4.

The humid microthermal climate (Figure 21) maximum and minimum recorded temperatures are, respectively, 90° and 0°F. In comparison with the igloos, the above-ground storehouses differ significantly. This difference is due largely to the fact that above-ground storehouses have none to very little protection against the extreme cold of winter and moderate to little protection from the heat of summer. Even so, the temperatures exhibited by above-ground storehouses are still relatively moderate. Table 4 details the quantification analysis of above-ground storehouses for this climatic zone.

IGLOOS AND ABOVE-GROUND STOREHOUSES

The combined plots of igloos and above-ground storehouses represent a curve that would be the best statistical fit between the two. Figures 23 through 26 display the individual climatic zones; and Figure 27 displays all climatic zones combined. The combination of igloos and above-ground storehouses does not alter the curves significantly and, therefore, the

generalizations of the previous quantification analysis can be repeated. However, to alleviate repetition, only the quantification analysis table is included in this report (Table 5).

TABLE 5. Quantification Analysis -- Igloos and Above-Ground Storehouses.

Climatic zone	Temperature, °F		Quantification		Single day frequency of occurrence, years	
	Max	Min	Max	Min	Max	Min
Tropical	108	60	1.0000	0.0003	(a)	9.13
Dry	119	20	0.9998	0.0004	14.0	6.84
Humid mesothermal	105	20	0.9999	0.0016	27.4	1.71
Humid microthermal	90	0	0.9997	0.0003	9.4	0.91
All climates	119	5	1.0000	0.0029	0	0.94

[a] Extremely rare.

The most likely user of the data reported herein is not expected to be a statistical expert. However, the user will most likely have a general knowledge or feel for data displayed in Gaussian format. Though it can be seen that the curve of Figure 27 is not symmetrical and, therefore, cannot be simple Gaussian, an attempt has been made to squeeze the Figure 27 data into simple Gaussian format. To do this, nominal 3 sigma one-sided distributed temperature values were plotted commensurate to the 0.003 and 0.997 cumulative probabilities of Figure 27 on Gaussian paper. A line was then drawn between these two temperature values. The result is Figure 28. This method is not, of course, in the most precise statistical traditions; however, the major user of these data is expected to be generally interested in the 3 sigma or more extreme values.

The plot of Figure 28 now does away with end points. Therefore, the majority user can derive any temperature commensurate to any quantification. Also, the format of Figure 28 is a constant reminder that there is, theoretically, no such thing as the "end points" shown in the other figures reported herein. Keep in mind that the data this report draws upon is representative of a large sample. In all probability the reported end points are within a single, or at most, a few degrees Fahrenheit of what would be measured over a much longer period of time.

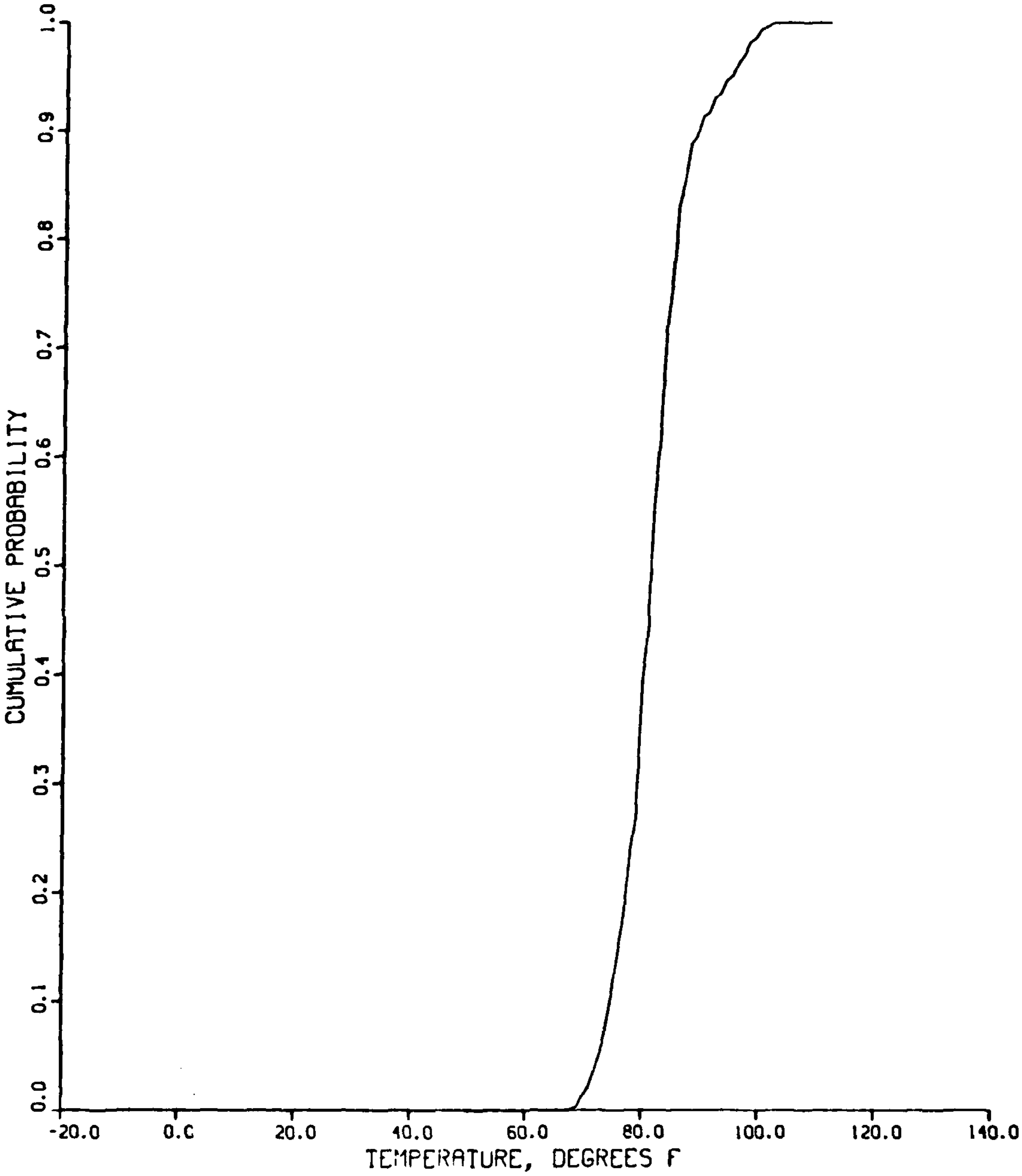

FIGURE 13. Igloos Consolidated -- Cumulative Probability of Tropical Climates.

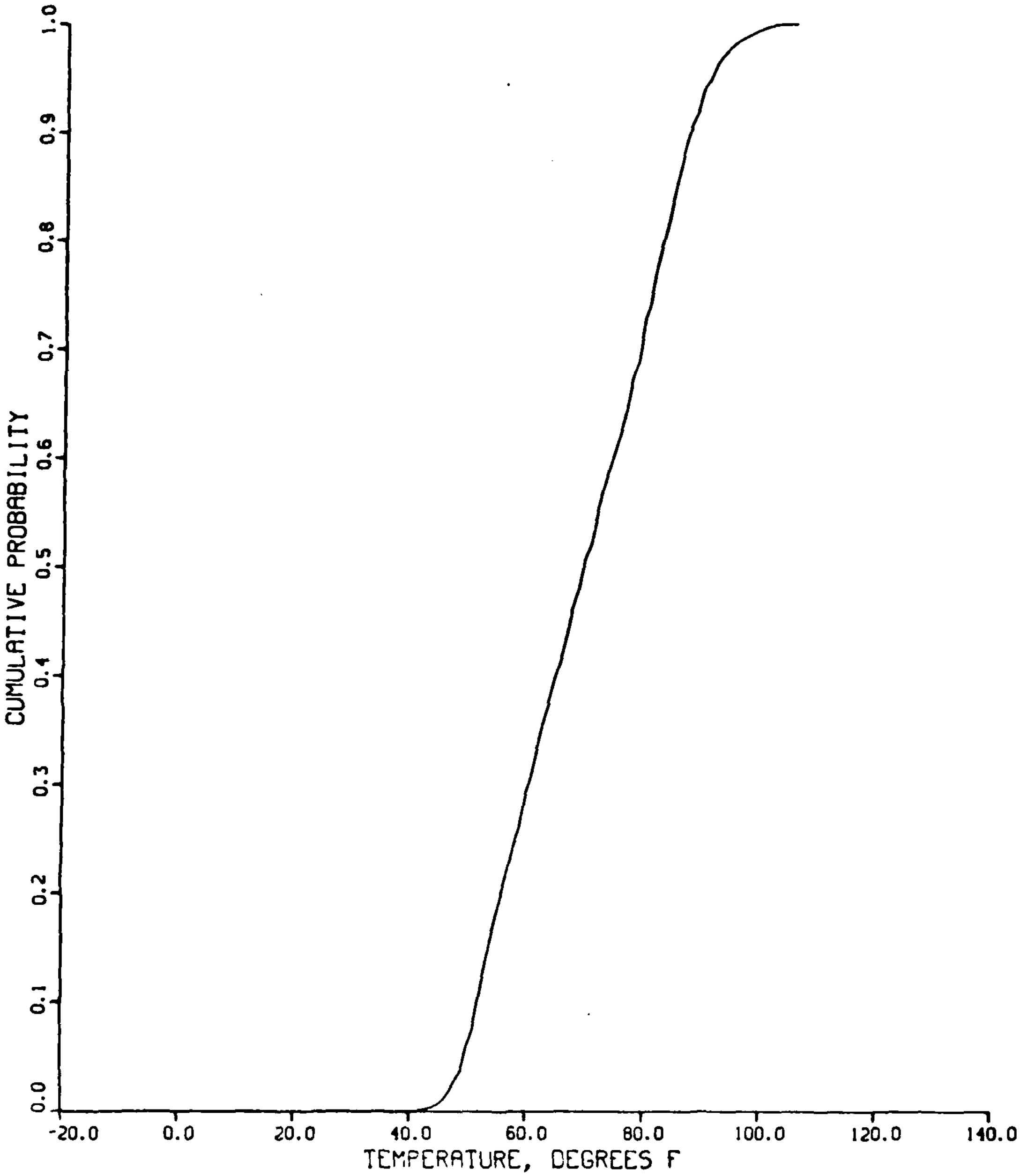

FIGURE 14. Igloos Consolidated -- Cumulative Probability of Dry Climates.

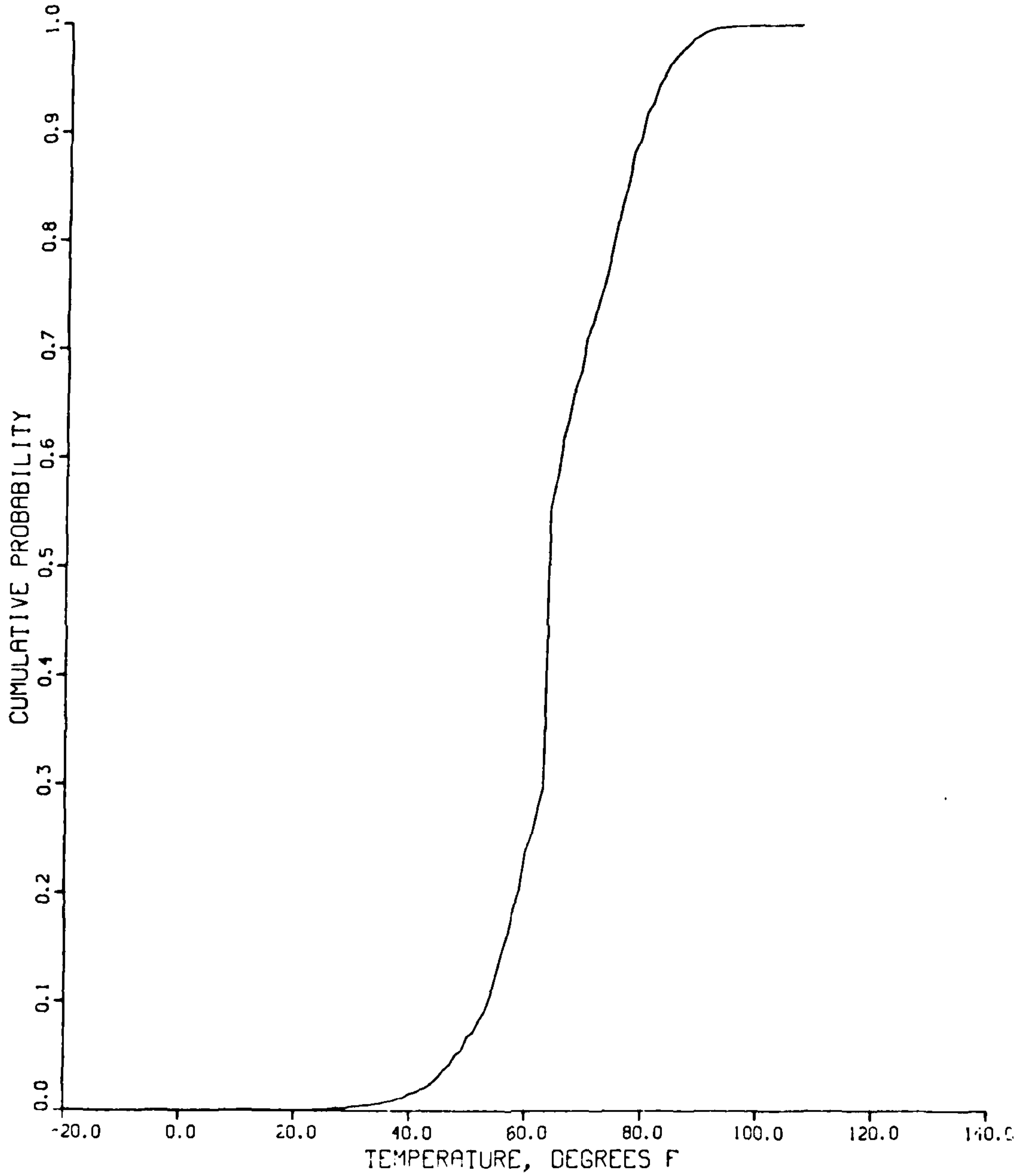

FIGURE 15. Igloos Consolidated -- Cumulative Probability of Humid Mesothermal Climates.

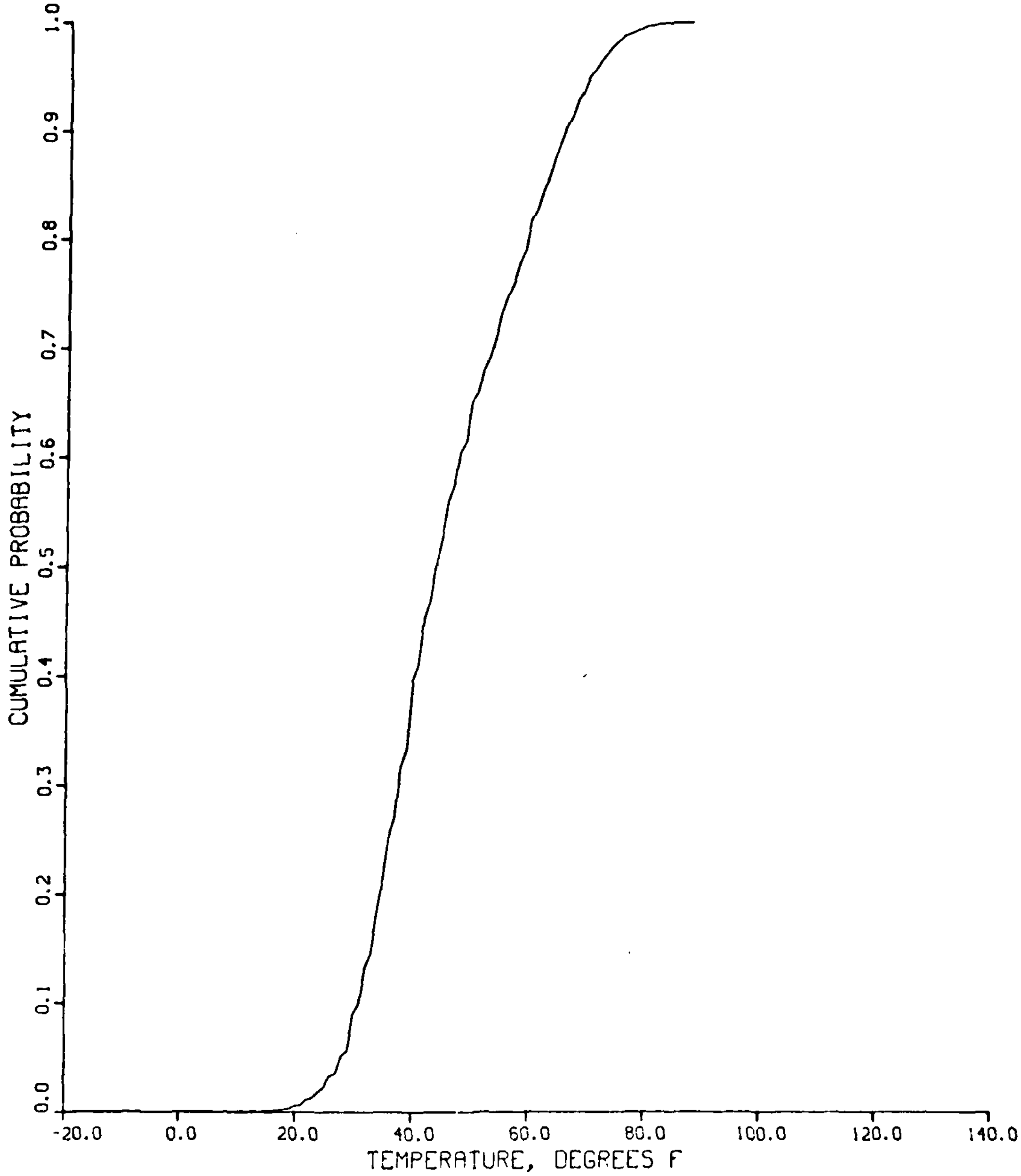

FIGURE 16. Igloos Consolidated -- Cumulative Probability of Humid Microthermal Climates.

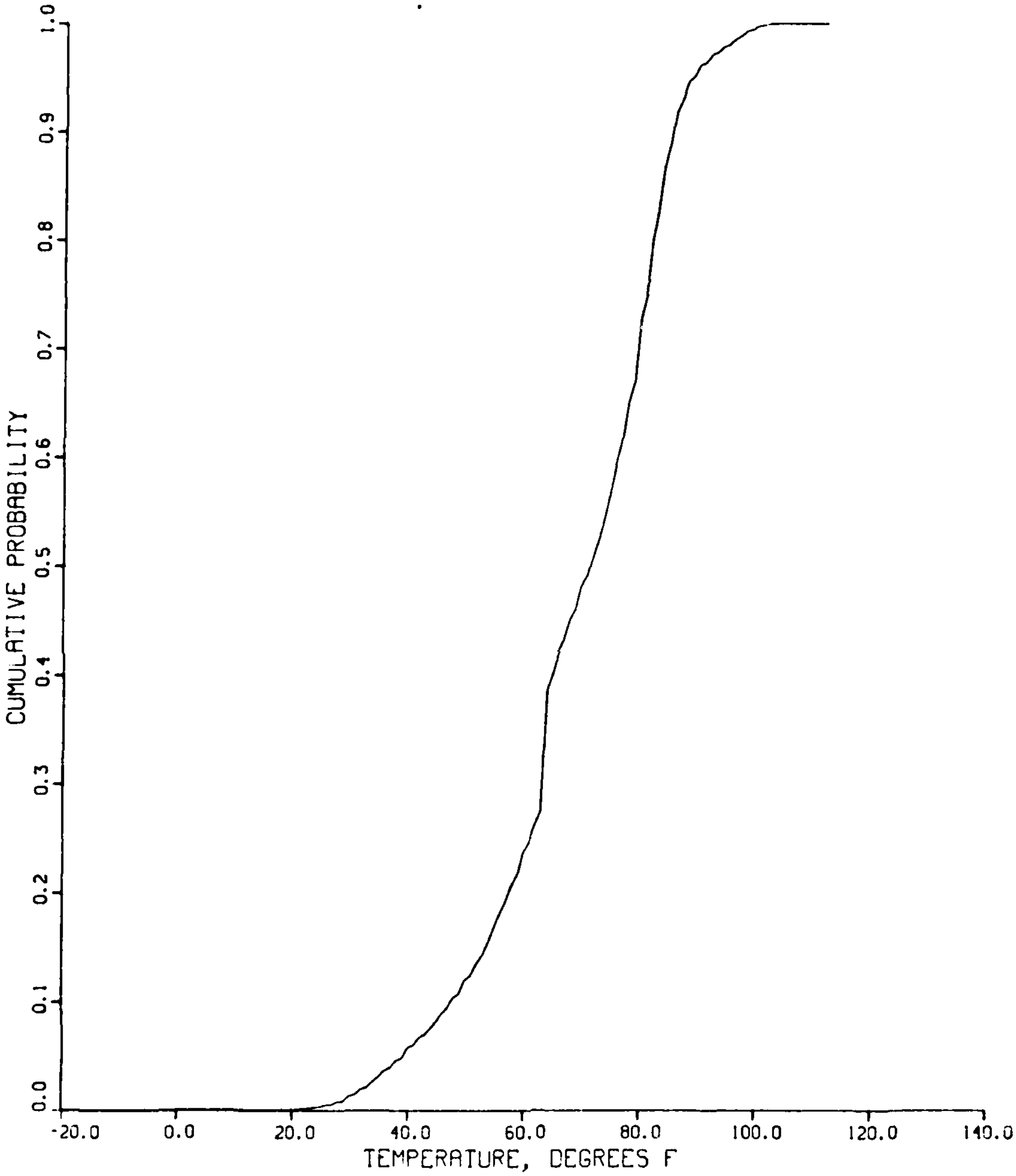

FIGURE 17. Igloos Consolidated -- Cumulative Probability of All Climates.

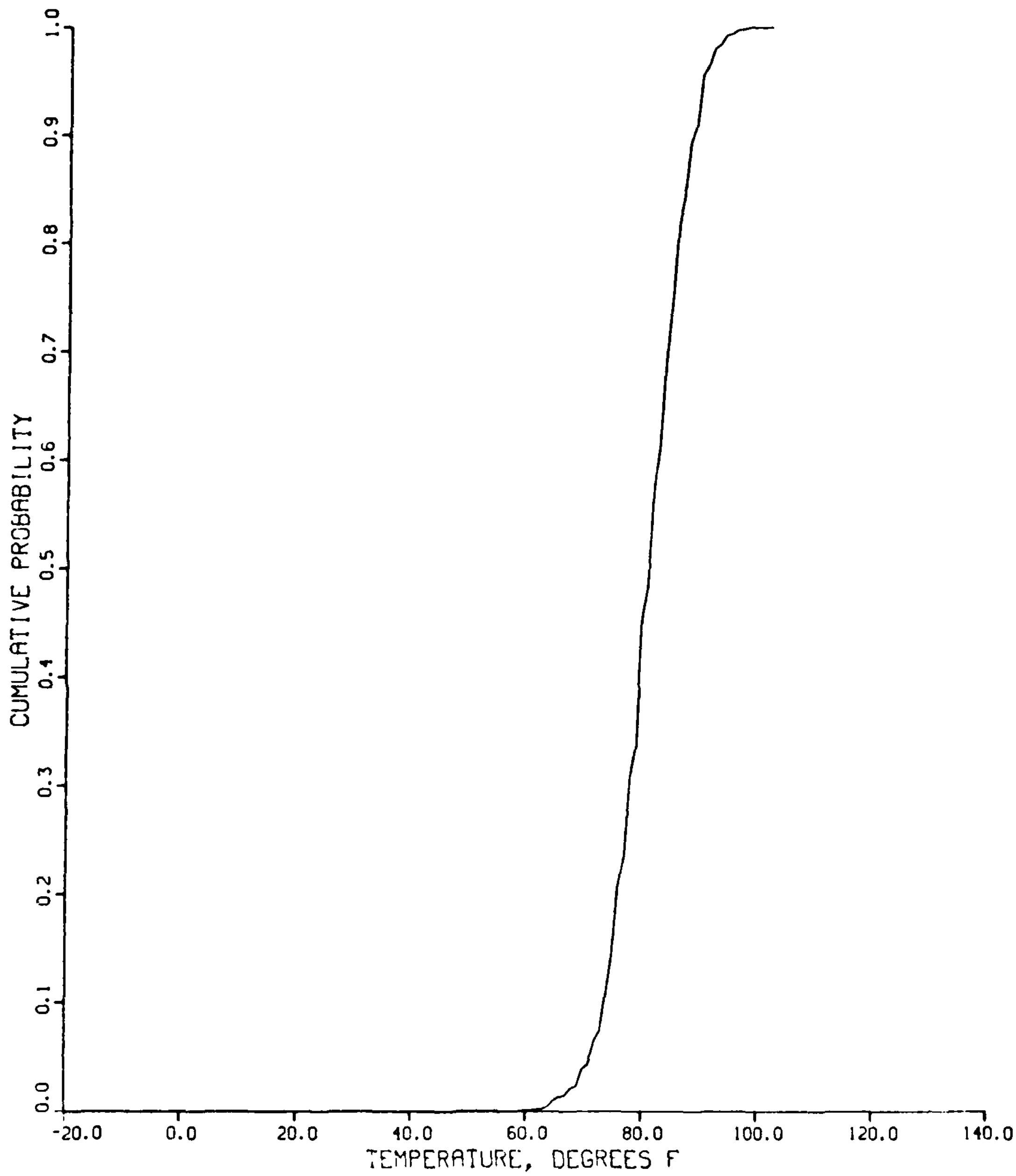

FIGURE 18. Above-Ground Storehouses Consolidated -- Cumulative Probability of Tropical Climates.

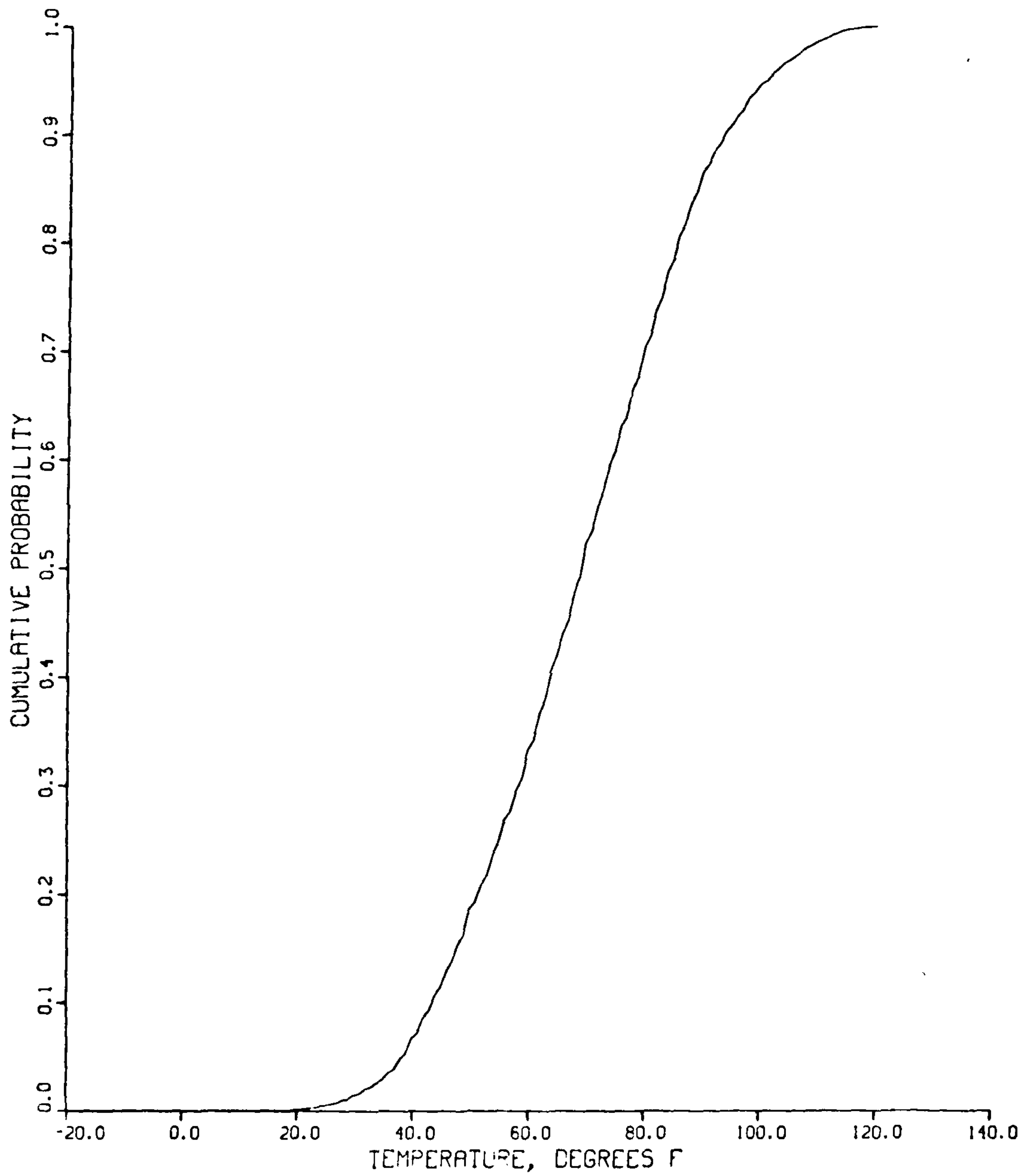

FIGURE 19. Above-Ground Storehouses Consolidated -- Cumulative Probability of Dry Climates.

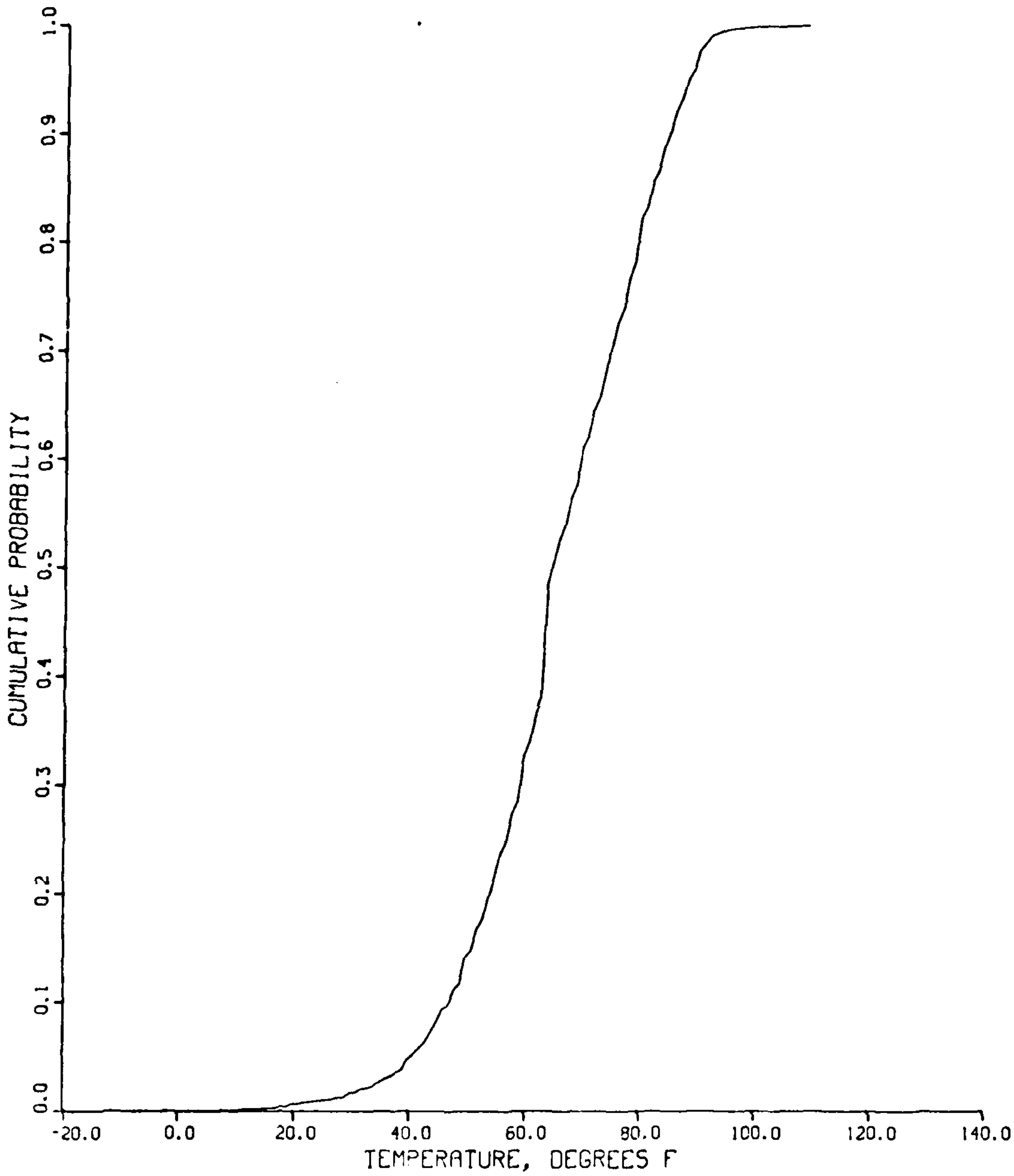

FIGURE 20. Above-Ground Storehouses Consolidated -- Cumulative Probability of Humid Mesothermal Climates.

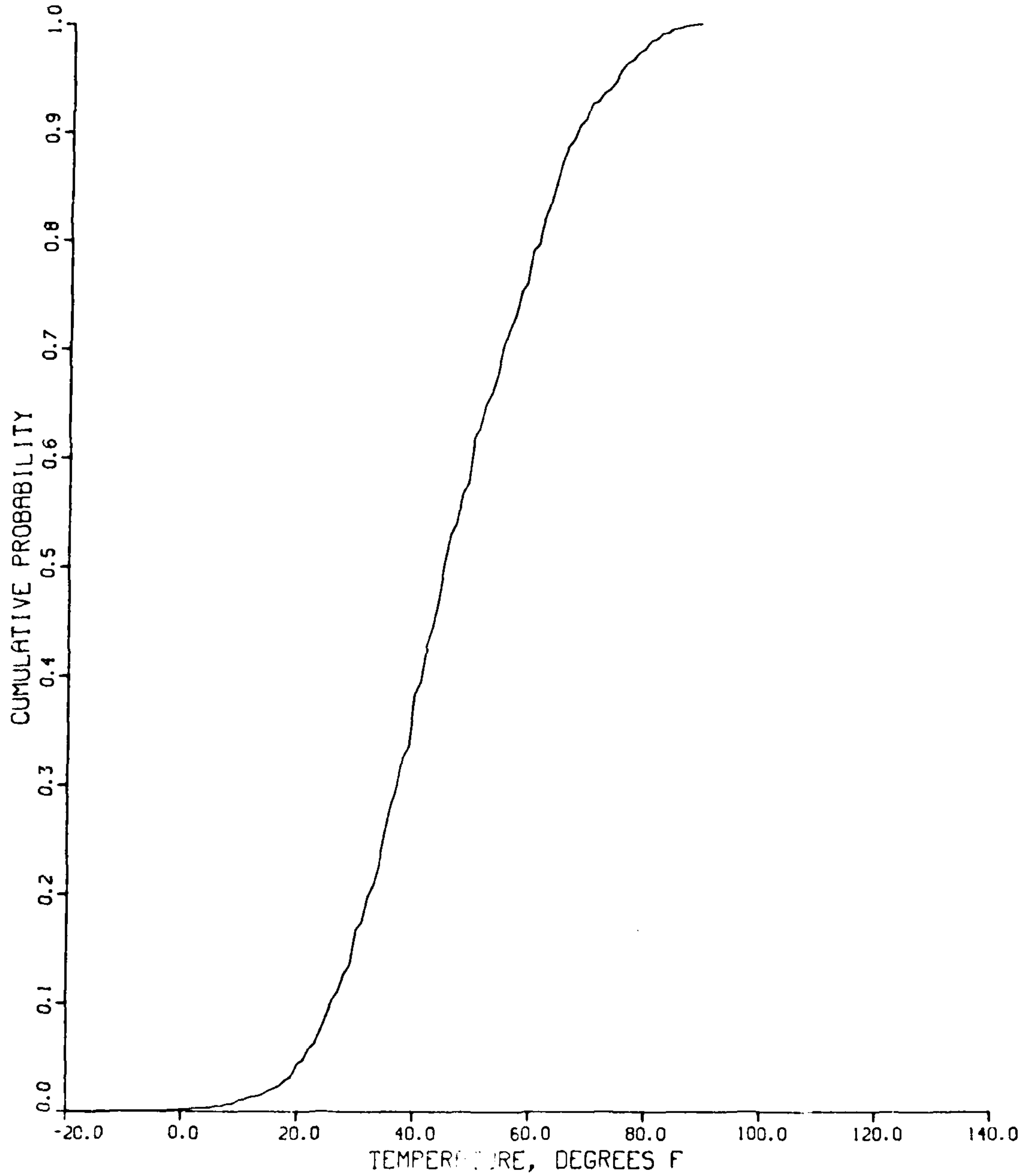

FIGURE 21. Above-Ground Storehouses Consolidated -- Cumulative Probability of Humid Microthermal Climates.

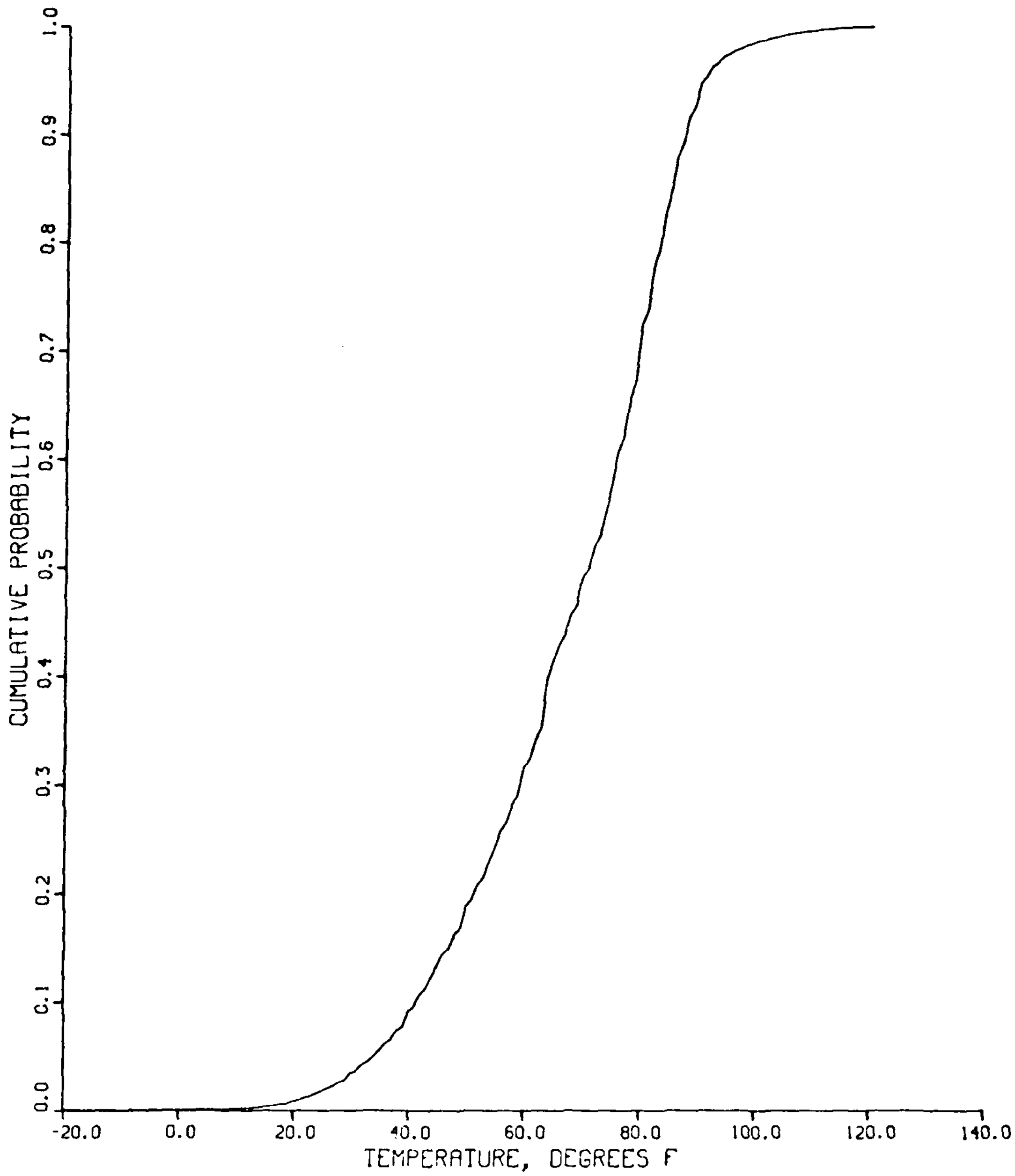

FIGURE 22. Above-Ground Storehouses Consolidated -- Cumulative Probability of All Climates.

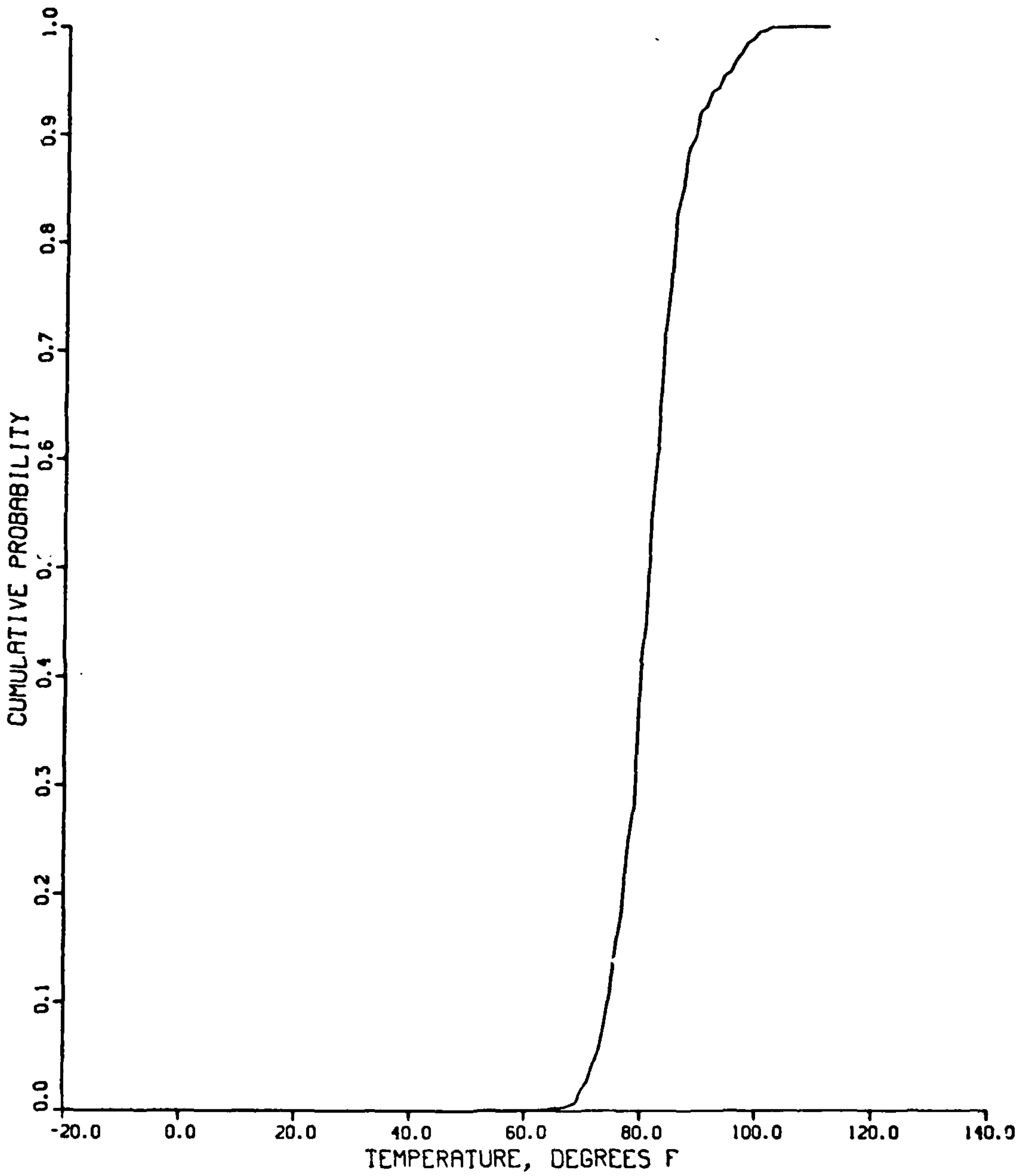

FIGURE 23. Igloos and Above-Ground Storehouses Consolidated -- Cumulative Probability of Tropical Climates.

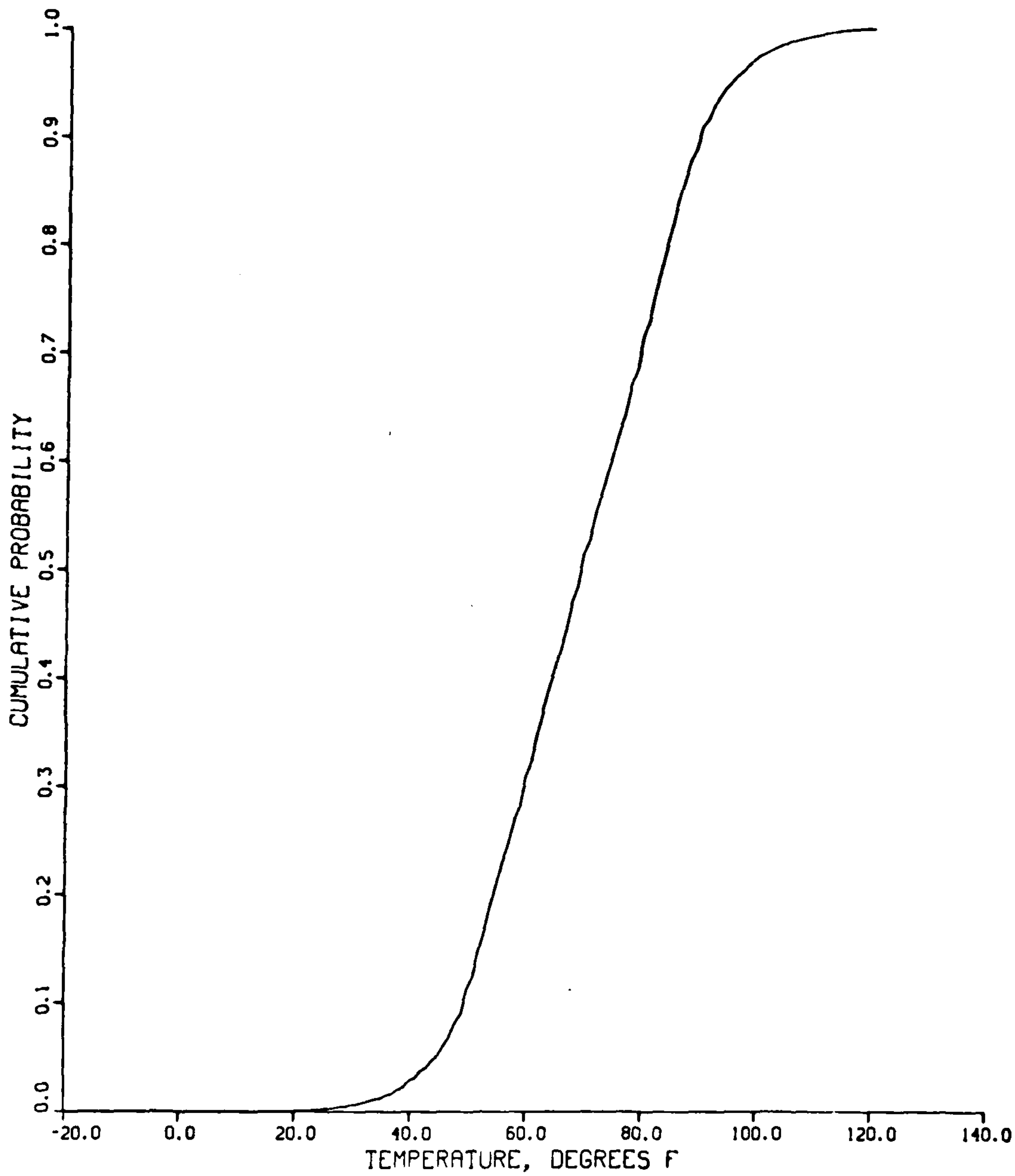

FIGURE 24. Igloos and Above-Ground Storehouses Consolidated -- Cumulative Probability of Dry Climates.

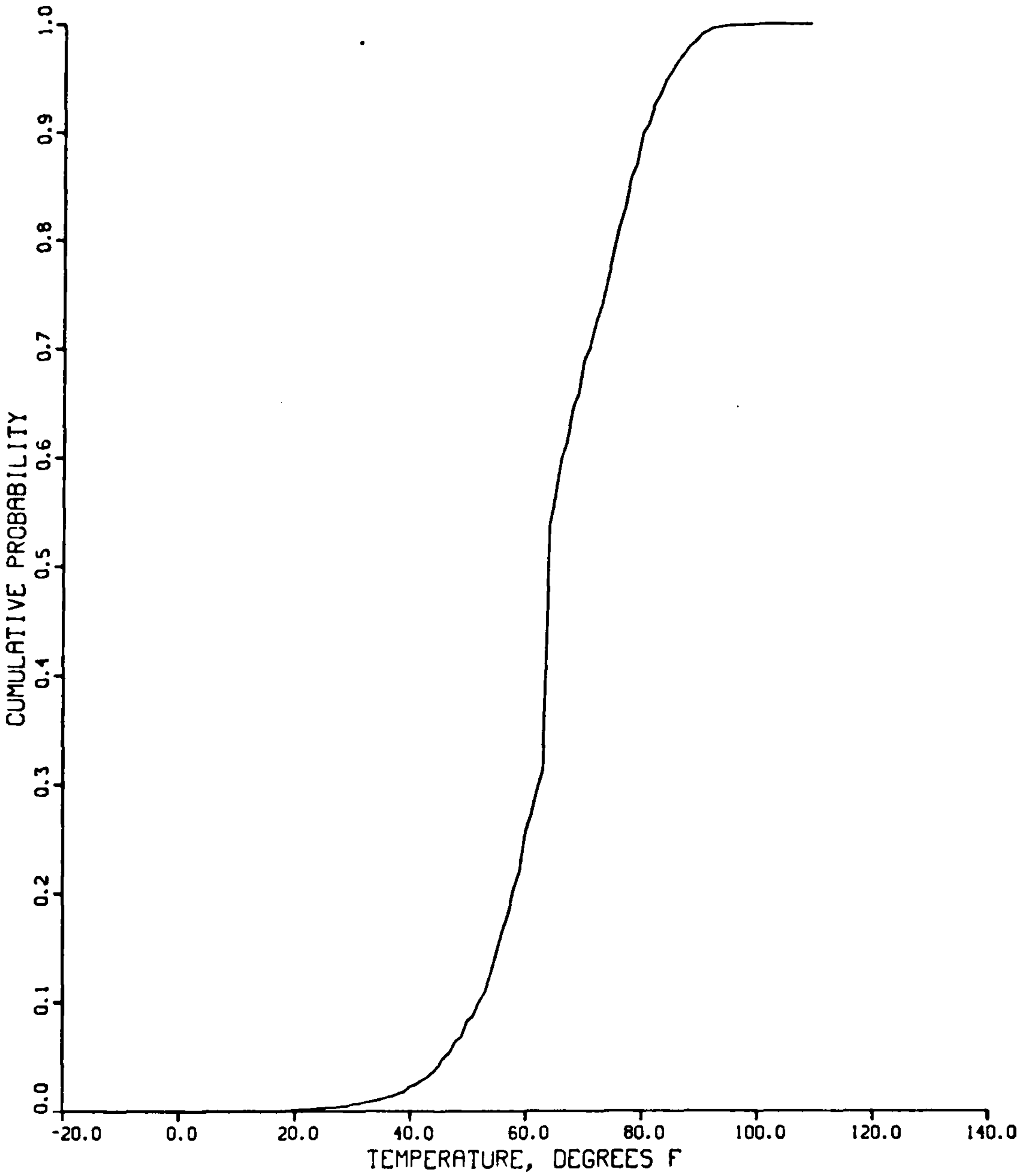

FIGURE 25. Igloos and Above-Ground Storehouses Consolidated -- Cumulative Probability of Humid Mesothermal Climates.

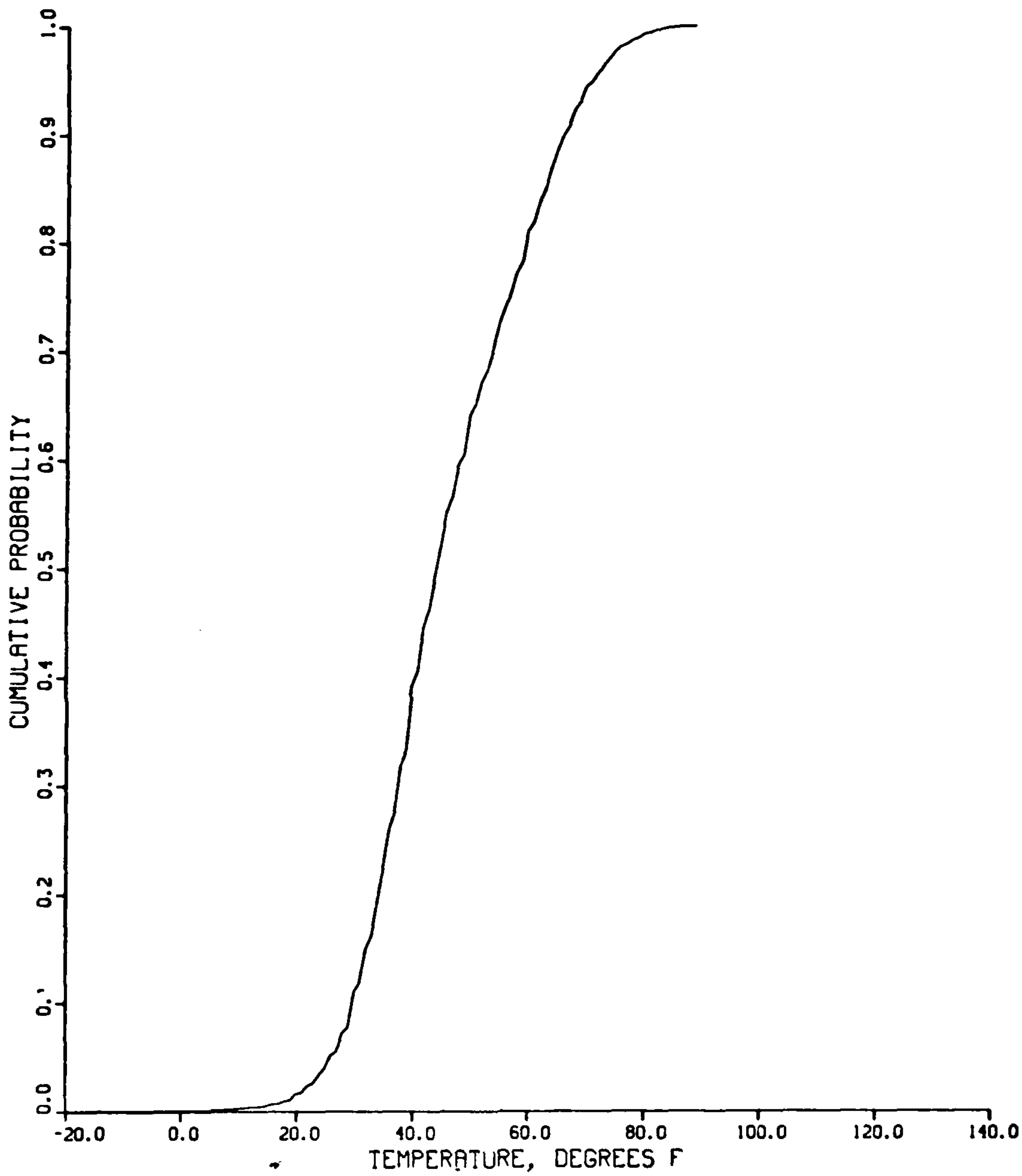

FIGURE 26. Igloos and Above-Ground Storehouses Consolidated -- Cumulative Probability of Humid Microthermal Climates.

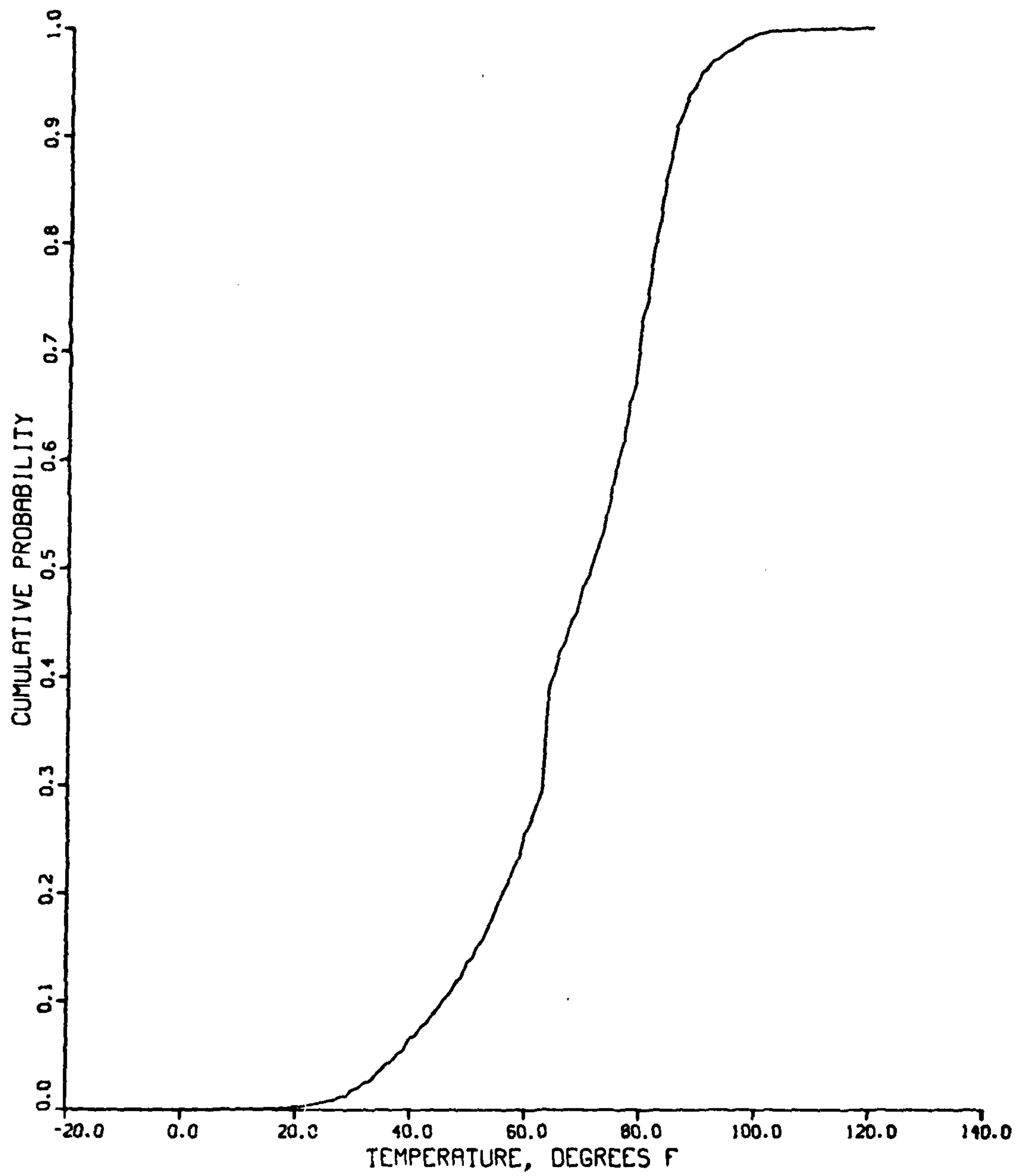

FIGURE 27. Igloos and Above-Ground Storehouses Consolidated -- Cumulative Probability of All Climates.

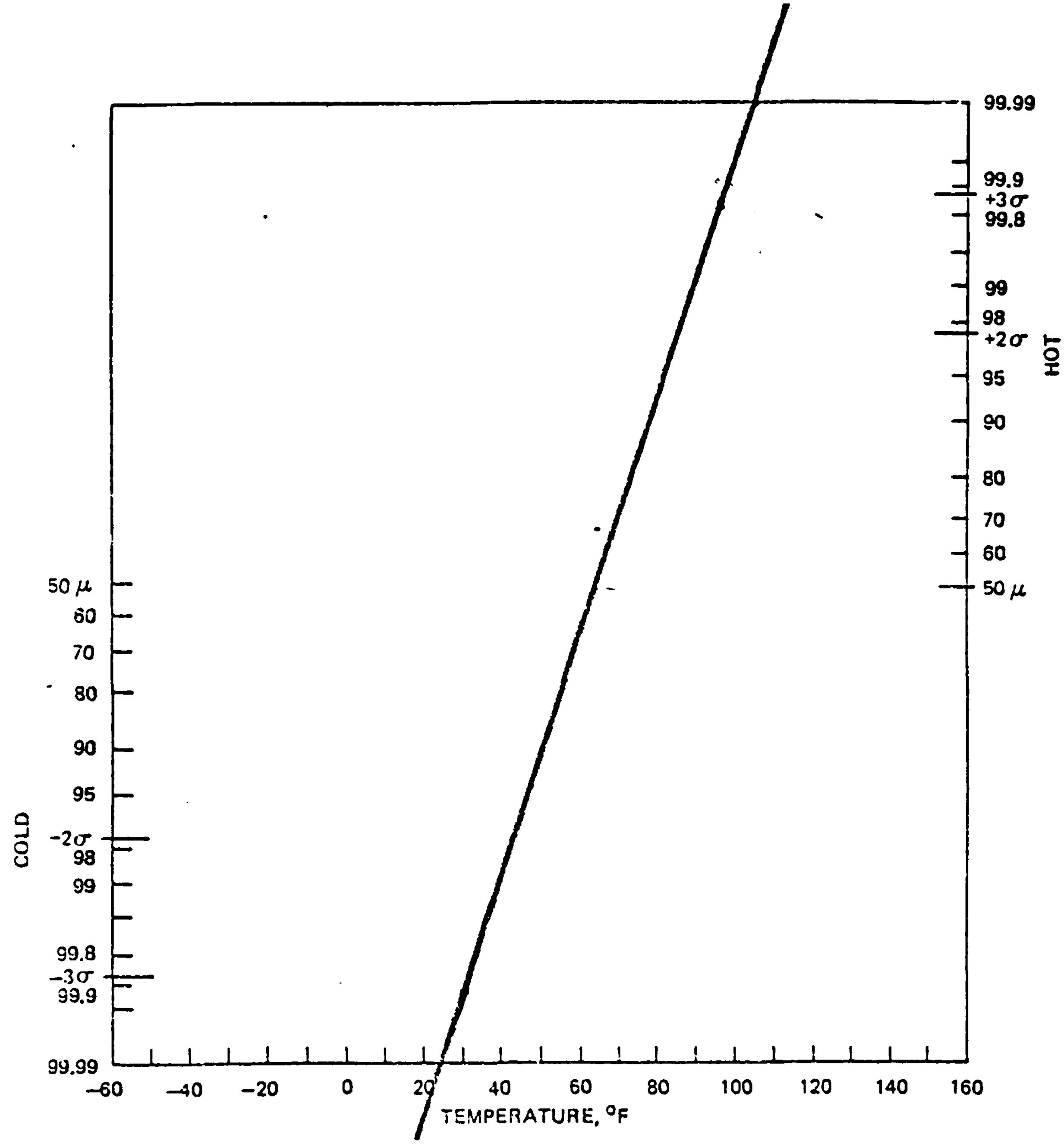

FIGURE 28. Guassian Representation of All Covered Storage - Worldwide.

CONCLUSIONS

The thermal exposure to which materiel is subjected while stored in any structure is, in fact, benign anywhere in the world. For design purposes, the temperature range experienced, covering 99.7% (3 sigma) of the time in existing military storehouses on a worldwide basis is +30° to +95°F. The extreme data representative of all the climatological divisions of the earth, as per Koppen, and shown in Tables 3 through 5 give no credence whatsoever to the assignment of -65° or 160°F temperature values for design or degradation of materiel during this event of the factory-to-target sequence.

The world can usefully be partitioned into the same divisions provided by the climatologists to display data on the thermal exposure of materiel in a manner useful to the project manager and designers. The least number of these divisions needed to describe the thermal exposure of materiel in enclosed storage is four, as per Koppen's system.

Appendix A

CLASSIFICATION OF MAGAZINES

Storage magazines differ in construction and deployment for the type of ammunition that is to be stowed. The storage magazines from which the temperature data have been collected differ greatly in their classification range from "explosive hazard magazines" to storehouses. Their construction, labeling, maintenance, etc., and the frequency at which temperature measurements were taken are in accordance with Ammunition Ashore Handling, Stowing, and Shipping, OP-5, Vol. 1, fourth revision. The letter designations as established by OP-5 are presented in Table A-1, so that the reader will have no difficulty in distinguishing between types of magazines that are found at the specified locations in the tropics.

In order to indicate the type of magazine, OP-5 requires that the letter T is added if the magazine is earth covered and barricaded; the letter C is added if the magazine is earth covered but the door is not barricaded; and the letter S is added if the magazine is not earth covered but is barricaded.

TABLE A-1. Construction, Use, and Capacities.

L to N inclusive and SC and Y fire hazard -- powder (bulk, semifixed or bag ammunition), pyrotechnics, ignition fuzes and primers, small arms, smoke drums, chemical ammunition.

Dimensions (nominal), ft	Normal explosive limit, lb	Letter designator
50 x 100	1,000,000	L
25 x 80 triple arch	1,000,000	L
52 dome (Corbetta type)	1,000,000	D
50 x 60	300,000	M
30 x 50	125,000	N
25 x 48	125,000	N
25 x 40	125,000	N
Miscellaneous or nonstandard size	Dependent upon location, size, and construction	Y

TABLE A-1. (Contd.)

P and Z missile hazard -- projectile and fixed ammunition.

Dimensions (nominal), ft	Normal explosive limit, lb	Letter designator
50 x 100	500,000	P
25 x 80 triple arch	500,000 (total for three arches)	P
52 dome (Corbetta type)	500,000	D
Miscellaneous or non-standard size	150,000	Z

A to K inclusive and W and X explosion hazard -- high explosive (bulk, depth charges, mines, warheads, bombs, etc.) fuzes, detonators, exploders, black powder.

Dimensions (nominal), ft	Normal use	Normal explosive limit, lb	Letter desig-nator
25 x 80 arch type (igloo)	High explosives	500,000	A
25 x 50 arch type (igloo)	High explosives	250,000	B
25 x 40 arch type (igloo)	High explosives	250,000	B
39 x 44 or 32 x 44 (war-head type)	High explosives	500,000	W
12 x 17 (box type)	Black powder	20,000	E
Miscellaneous or nonstandard size	High explosives	Dependent upon size, location, and construction	X
25 x 20 arch type (igloo)	Fuze and detonator	70,000	F

TABLE A-1. (Contd.)

Dimensions (nominal), ft	Normal use	Normal explosive limit, lb	Letter desig- nator
Dimensions vary (gallery or tunnel type)	High explosives	500,000	G
10 x 14	Fuze and detonator	15,000	H
10 x 7	Fuze and detinator	7,500	H
6 x 8-2/3 (keyport type)	High explosives	4,000	K

Dimensions (nominal), ft	Type	Letter designator
25 x 68	Smoke drum type	SD
25 x 34	Smoke drum type	SD
25 x 51	Smoke drum type	SD
...	All inert storehouses	SH

Type of hazard	Letter designator
Explosive hazard magazine	X
Fire hazard magazine	Y
Missile hazard magazine	Z

Appendix B

DATA HANDLING/DEFINITIONS

DATA HANDLING

Temperature data from logbooks, monthly cards, and daily sheets are keypunched in formats as shown in Figure B-1 and the flow of data handling is as shown in Figure B-2.

The keypunched temperature data cards are presorted per storage location, year of the data, and type of magazine from which the temperature data were taken.

The data cards are prepared as input to Program TTAPE which reads the input and writes the temperature data onto a digital magnetic tape (TTAPE Raw Data) and also prints out a set of tabulations showing the files written on this tape via UNIVAC 1110 computer. Data from each magazine represent a file, and a sample of the tabulation is shown in Figure B-3. All manipulations and reductions of the raw temperature data are done using the tape TTAPE.

Program TTEMP is then prepared with TTAPE as input and via the computer it sorts and counts the minimum and maximum daily temperature data into stalls of temperature data from -20° to 120°F at a 1-degree increment. This program outputs the temperature frequency data on punched cards and tabulations as shown in Figure B-4.

The temperature frequency data cards are then checked for obvious bad data points, if any, and eliminated prior to being prepared as input to Program CTAPE or Program FCON.

When the Program CTAPE option is used, the temperature frequency card data are written on a digital magnetic tape (CTAPE Frequency Data) and a list of files of CTAPE is printed out via the computer showing what data (i.e., storage location, level, year of data, etc.) were written on what file of CTAPE. Program CTAPE option is used when obtaining temperature frequency data which are summed or consolidated over many levels, many locations, and many years, such that manipulation of the tape input is more efficient and flexible in the computer usage than the handling of voluminous card input.

Program CCON is then prepared for the computer run using the magnetic tape CTAPE as input to compute the consolidated temperature frequency data. The computed data are similarly punched out on cards and printed out in tabulations as the Program TTEMP.

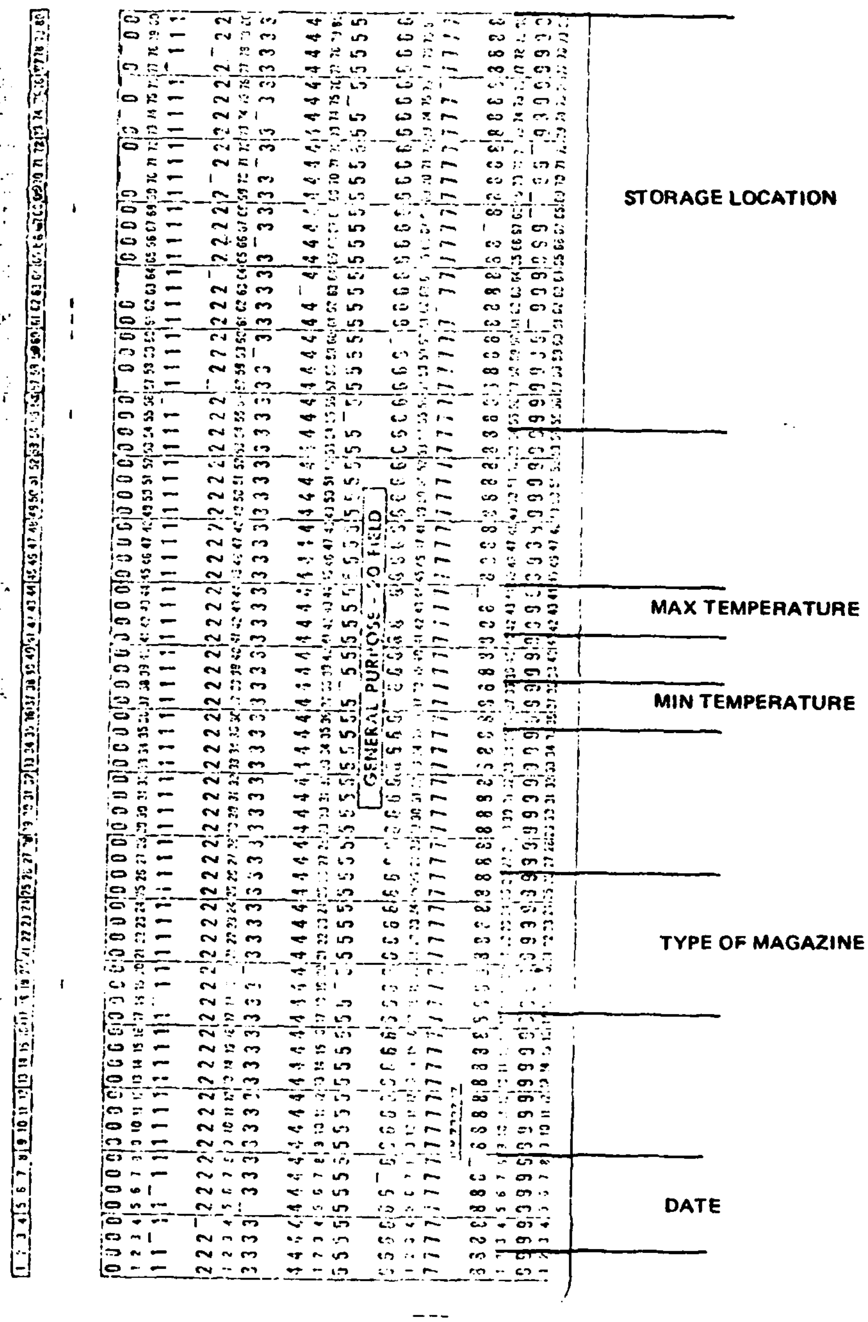

FIGURE B-1. Sample Input Card With Data Fields.

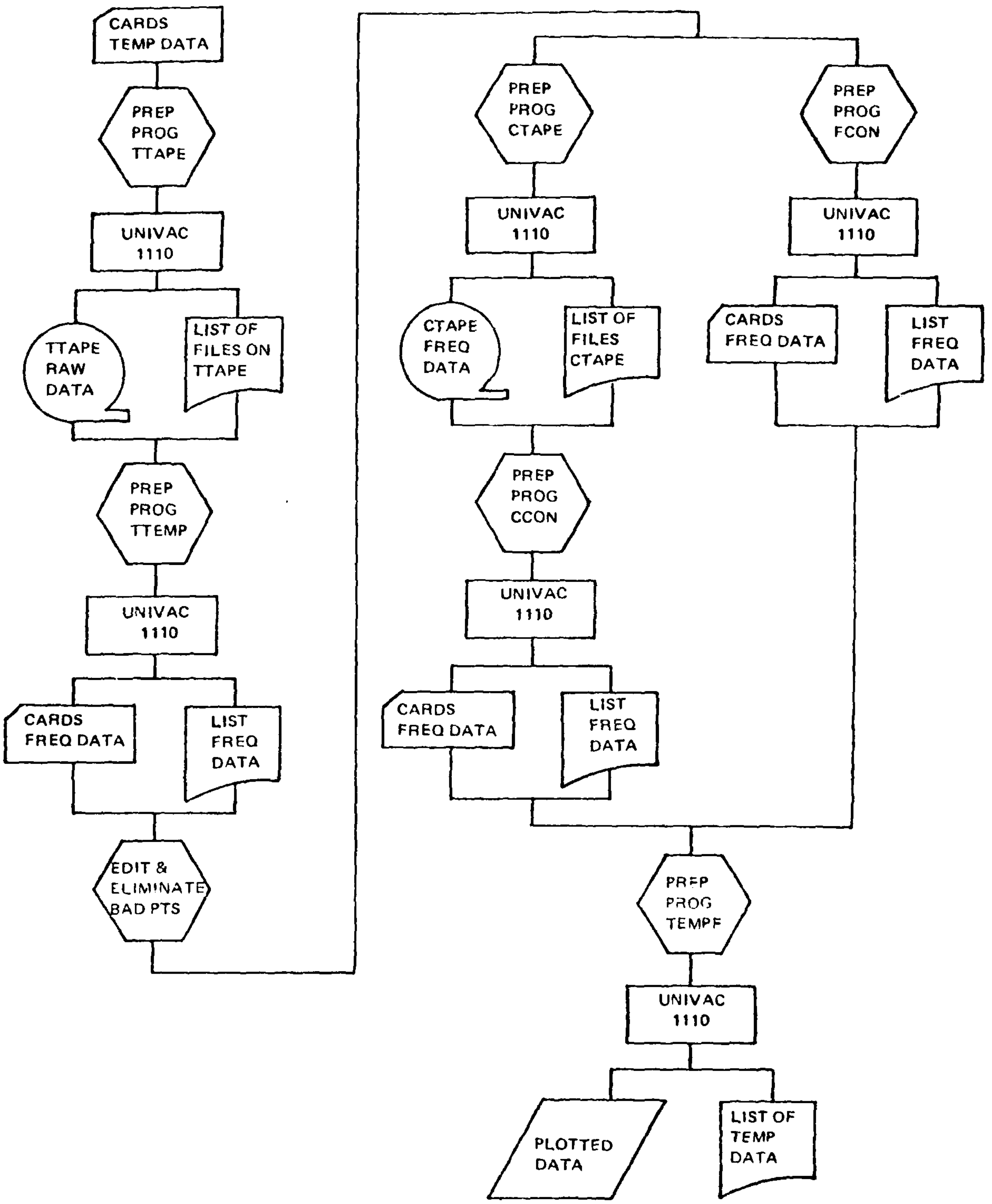
CARDS
TEMP DATA
PREP
PROG
TTAPE
UNIVAC
1110
TTAPE
RAW
DATA
LIST OF
FILES ON
TTAPE
PREP
PROG
TTEMP
UNIVAC
1110
CARDS
FREQ DATA
LIST
FREQ
DATA
EDIT &
ELIMINATE
BAD PTS
PREP
PROG
CTAPE
UNIVAC
1110
CTAPE
FREQ
DATA
LIST OF
FILES
CTAPE
PREP
PROG
CCON
UNIVAC
1110
CARDS
FREQ DATA
LIST
FREQ
DATA
PREP
PROG
FCON
UNIVAC
1110
CARDS
FREQ DATA
LIST
FREQ
DATA
PREP
PROG
TEMPF
UNIVAC
1110
PLOTTED
DATA
LIST OF
TEMP
DATA

FIGURE B-2.

FILE NO.	LEVEL	HULL NO.	DATA PTS	YEAR	DATE OF RUN
17	IGLOO	S WASHINGTON	212	66	C7/24/79
18	ABVNGD	S WASHINGTON	115	66	07/24/79
19	IGLOO	S WASHINGTON	109	67	07/24/79
20	ABVNGD	S WASHINGTON	44	67	07/24/79

FIGURE B-3.

TAPE NO.: 7201 FILE NO.: 17 IDENTIFICATION: LEVEL IGLOO YR 66 S WASHINGTON ON TAPE 07/24/79

MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX	MIN	MAX
40	48	44	48	35	42	40	42	40	45	36	42	40	48	40	46	38	46	41	45
42	47	41	45	39	47	39	45	40	47	38	45	37	47	40	44	46	47	41	45
37	44	40	43	42	46	40	44	46	47	36	44	42	50	40	45	37	50	39	47
40	51	42	44	39	53	36	51	41	49	40	47	35	51	39	53	41	50	40	45
37	50	42	46	48	50	40	47	45	52	36	50	46	50	38	45	40	60	47	55
45	55	43	51	40	60	45	51	48	57	43	56	45	55	44	50	47	55	45	51
46	47	47	48	50	50	47	48	40	57	44	51	47	56	44	51	46	62	45	61
48	55	50	66	56	65	52	57	46	62	47	52	51	63	51	56	54	66	50	58
50	63	50	55	55	63	55	61	50	61	50	54	55	65	55	60	55	66	50	58
65	76	55	60	58	65	55	60	58	63	61	69	58	63	60	72	56	63	68	70
58	63	58	65	56	62	59	67	56	61	56	68	57	64	60	72	57	64	56	72
60	65	62	65	61	65	62	65	60	66	63	73	58	66	60	75	65	70	60	68
63	75	59	73	60	76	65	70	64	65	67	68	61	63	64	66	59	62	65	65
62	63	62	63	65	67	60	68	62	76	59	69	57	79	65	70	60	65	64	75
60	68	63	75	57	70	56	64	60	65	61	68	58	62	56	66	47	65	60	60
65	67	60	60	60	62	63	64	55	56	62	63	58	60	56	59	60	61	54	63
58	72	55	66	50	70	60	72	50	55	50	55	50	76	52	61	50	51	45	60
54	58	50	57	51	56	50	58	54	56	54	59	51	56	50	54	48	57	48	54
51	55	48	53	50	52	48	52	45	45	50	51	46	50	48	54	47	50	41	52
50	51	47	51	48	51	46	49	43	47	48	50	42	48	46	51	45	49	39	50
49	50	44	49	48	66	38	48	47	48	45	51	43	48	45	50	45	50	40	50
46	50	43	44																

TMIN TOTAL DATA PTS: 212 NO. OF BAD PTS: 0 NO. OF DATA PTS USED: 212

TMAX TOTAL DATA PTS: 212 NO. OF BAD PTS: 0 NO. OF DATA PTS USED: 212

FIGURE B-4.

TAPE NO.: 7201 FILE NO.: 17 IDENTIFICATION: LEVEL IGLOO YR 66 S WASHINGTON ON TAPE 07/24/79

FREQUENCY OF TMAX SUB I

-20 DEG:	0	10 DEG:	0	40 DEG:	0	70 DEG:	6	100 DEG:	0
-19 DEG:	0	11 DEG:	0	41 DEG:	0	71 DEG:	0	101 DEG:	0
-18 DEG:	0	12 DEG:	0	42 DEG:	3	72 DEG:	5	102 DEG:	0
-17 DEG:	0	13 DEG:	0	43 DEG:	1	73 DEG:	2	103 DEG:	0
-16 DEG:	0	14 DEG:	0	44 DEG:	6	74 DEG:	0	104 DEG:	0
-15 DEG:	0	15 DEG:	0	45 DEG:	10	75 DEG:	4	105 DEG:	0
-14 DEG:	0	16 DEG:	0	46 DEG:	4	76 DEG:	4	106 DEG:	0
-13 DEG:	0	17 DEG:	0	47 DEG:	11	77 DEG:	0	107 DEG:	0
-12 DEG:	0	18 DEG:	0	48 DEG:	9	78 DEG:	0	108 DEG:	0
-11 DEG:	0	19 DEG:	0	49 DEG:	4	79 DEG:	1	109 DEG:	0
-10 DEG:	0	20 DEG:	0	50 DEG:	18	80 DEG:	0	110 DEG:	0
-9 DEG:	0	21 DEG:	0	51 DEG:	15	81 DEG:	0	111 DEG:	0
-8 DEG:	0	22 DEG:	0	52 DEG:	5	82 DEG:	0	112 DEG:	0
-7 DEG:	0	23 DEG:	0	53 DEG:	3	83 DEG:	0	113 DEG:	0
-6 DEG:	0	24 DEG:	0	54 DEG:	4	84 DEG:	0	114 DEG:	0
-5 DEG:	0	25 DEG:	0	55 DEG:	9	85 DEG:	0	115 DEG:	0
-4 DEG:	0	26 DEG:	0	56 DEG:	7	86 DEG:	0	116 DEG:	0
-3 DEG:	0	27 DEG:	0	57 DEG:	5	87 DEG:	0	117 DEG:	0
-2 DEG:	0	28 DEG:	0	58 DEG:	4	88 DEG:	0	118 DEG:	0
-1 DEG:	0	29 DEG:	0	59 DEG:	2	89 DEG:	0	119 DEG:	0
0 DEG:	0	30 DEG:	0	60 DEG:	9	90 DEG:	0	120 DEG:	0
1 DEG:	0	31 DEG:	0	61 DEG:	6	91 DEG:	0		
2 DEG:	0	32 DEG:	0	62 DEG:	6	92 DEG:	0		
3 DEG:	0	33 DEG:	0	63 DEG:	12	93 DEG:	0		
4 DEG:	0	34 DEG:	0	64 DEG:	4	94 DEG:	0		
5 DEG:	0	35 DEG:	0	65 DEG:	13	95 DEG:	0		
6 DEG:	0	36 DEG:	0	66 DEG:	9	96 DEG:	0		
7 DEG:	0	37 DEG:	0	67 DEG:	3	97 DEG:	0		
8 DEG:	0	38 DEG:	0	68 DEG:	6	98 DEG:	0		
9 DEG:	0	39 DEG:	0	69 DEG:	2	99 DEG:	0		

FIGURE B-4. (Contd.)

TAPE NO.: 7201 FILE NO.: 17 IDENTIFICATION: LEVEL IGLOO VR 66 S WASHINGTON ON TAPE 07/24/79

FREQUENCY OF TMIN SUB I

-20 DEG:	0	10 DEG:	0	40 DEG:	18	70 DEG:	0	100 DEG:	0
-19 DEG:	0	11 DEG:	0	41 DEG:	6	71 DEG:	0	101 DEG:	0
-18 DEG:	0	12 DEG:	0	42 DEG:	6	72 DEG:	0	102 DEG:	0
-17 DEG:	0	13 DEG:	0	43 DEG:	5	73 DEG:	0	103 DEG:	0
-16 DEG:	0	14 DEG:	0	44 DEG:	5	74 DEG:	0	104 DEG:	0
-15 DEG:	0	15 DEG:	0	45 DEG:	12	75 DEG:	0	105 DEG:	0
-14 DEG:	0	16 DEG:	0	46 DEG:	10	76 DEG:	0	106 DEG:	0
-13 DEG:	0	17 DEG:	0	47 DEG:	10	77 DEG:	0	107 DEG:	0
-12 DEG:	0	18 DEG:	0	48 DEG:	11	78 DEG:	0	108 DEG:	0
-11 DEG:	0	19 DEG:	0	49 DEG:	1	79 DEG:	0	109 DEG:	0
-10 DEG:	0	20 DEG:	0	50 DEG:	19	80 DEG:	0	110 DEG:	0
-9 DEG:	0	21 DEG:	0	51 DEG:	5	81 DEG:	0	111 DEG:	0
-8 DEG:	0	22 DEG:	0	52 DEG:	2	82 DEG:	0	112 DEG:	0
-7 DEG:	0	23 DEG:	0	53 DEG:	0	83 DEG:	0	113 DEG:	0
-6 DEG:	0	24 DEG:	0	54 DEG:	5	84 DEG:	0	114 DEG:	0
-5 DEG:	0	25 DEG:	0	55 DEG:	9	85 DEG:	0	115 DEG:	0
-4 DEG:	0	26 DEG:	0	56 DEG:	9	86 DEG:	0	116 DEG:	0
-3 DEG:	0	27 DEG:	0	57 DEG:	4	87 DEG:	0	117 DEG:	0
-2 DEG:	0	28 DEG:	0	58 DEG:	9	88 DEG:	0	118 DEG:	0
-1 DEG:	0	29 DEG:	0	59 DEG:	4	89 DEG:	0	119 DEG:	0
0 DEG:	0	30 DEG:	0	60 DEG:	16	90 DEG:	0	120 DEG:	0
1 DEG:	0	31 DEG:	0	61 DEG:	4	91 DEG:	0		
2 DEG:	0	32 DEG:	0	62 DEG:	6	92 DEG:	0		
3 DEG:	0	33 DEG:	0	63 DEG:	4	93 DEG:	0		
4 DEG:	0	34 DEG:	0	64 DEG:	3	94 DEG:	0		
5 DEG:	0	35 DEG:	2	65 DEG:	7	95 DEG:	0		
6 DEG:	0	36 DEG:	4	66 DEG:	0	96 DEG:	0		
7 DEG:	0	37 DEG:	4	67 DEG:	1	97 DEG:	0		
8 DEG:	0	38 DEG:	4	68 DEG:	1	98 DEG:	0		
9 DEG:	0	39 DEG:	6	69 DEG:	0	99 DEG:	0		

FIGURE B-4. (Contd.)

TAPE NO.: 7201 FILE NO.: 17 IDENTIFICATION: LEVEL IGLOO YR 66 S WASHINGTON ON TAPE 07/24/79

FREQUENCY OF (TMIN AND TMAX) SUB I

-20 DEG:	0	10 DEG:	0	40 DEG:	18	70 DEG:	6	100 DEG:	0
-19 DEG:	0	11 DEG:	0	41 DEG:	6	71 DEG:	0	101 DEG:	0
-18 DEG:	0	12 DEG:	0	42 DEG:	9	72 DEG:	5	102 DEG:	0
-17 DEG:	0	13 DEG:	0	43 DEG:	6	73 DEG:	2	103 DEG:	0
-16 DEG:	0	14 DEG:	0	44 DEG:	11	74 DEG:	0	104 DEG:	0
-15 DEG:	0	15 DEG:	0	45 DEG:	22	75 DEG:	4	105 DEG:	0
-14 DEG:	0	16 DEG:	0	46 DEG:	14	76 DEG:	4	106 DEG:	0
-13 DEG:	0	17 DEG:	0	47 DEG:	21	77 DEG:	0	107 DEG:	0
-12 DEG:	0	18 DEG:	0	48 DEG:	20	78 DEG:	0	108 DEG:	0
-11 DEG:	0	19 DEG:	0	49 DEG:	5	79 DEG:	1	109 DEG:	0
-10 DEG:	0	20 DEG:	0	50 DEG:	37	80 DEG:	0	110 DEG:	0
-9 DEG:	0	21 DEG:	0	51 DEG:	20	81 DEG:	0	111 DEG:	0
-8 DEG:	0	22 DEG:	0	52 DEG:	7	82 DEG:	0	112 DEG:	0
-7 DEG:	0	23 DEG:	0	53 DEG:	3	83 DEG:	0	113 DEG:	0
-6 DEG:	0	24 DEG:	0	54 DEG:	9	84 DEG:	0	114 DEG:	0
-5 DEG:	0	25 DEG:	0	55 DEG:	18	85 DEG:	0	115 DEG:	0
-4 DEG:	0	26 DEG:	0	56 DEG:	16	86 DEG:	0	116 DEG:	0
-3 DEG:	0	27 DEG:	0	57 DEG:	9	87 DEG:	0	117 DEG:	0
-2 DEG:	0	28 DEG:	0	58 DEG:	13	88 DEG:	0	118 DEG:	0
-1 DEG:	0	29 DEG:	0	59 DEG:	6	89 DEG:	0	119 DEG:	0
0 DEG:	0	30 DEG:	0	60 DEG:	25	90 DEG:	0	120 DEG:	0
1 DEG:	0	31 DEG:	0	61 DEG:	10	91 DEG:	0		
2 DEG:	0	32 DEG:	0	62 DEG:	12	92 DEG:	0		
3 DEG:	0	33 DEG:	0	63 DEG:	16	93 DEG:	0		
4 DEG:	0	34 DEG:	0	64 DEG:	7	94 DEG:	0		
5 DEG:	0	35 DEG:	2	65 DEG:	20	95 DEG:	0		
6 DEG:	0	36 DEG:	4	66 DEG:	9	96 DEG:	0		
7 DEG:	0	37 DEG:	4	67 DEG:	4	97 DEG:	0		
8 DEG:	0	38 DEG:	4	68 DEG:	7	98 DEG:	0		
9 DEG:	0	39 DEG:	6	69 DEG:	2	99 DEG:	0		

FIGURE B-4. (Contd.)

The consolidated temperature frequency data cards from Program CCON are then prepared as input to Program TEMPF, which takes this input and computes the cumulative frequency data and the cumulative probability data of the consolidated temperature data for minimum and maximum temperatures separately and for minimum and maximum temperatures combined. The program outputs plotted and tabulated data, as shown in Figure B-5.

Program FCON option is used when the temperature frequency data cards are relatively small in volume and the consolidation of the data is limited. The program then outputs the consolidated temperature frequency data cards and a set of tabulations listing the consolidated temperature frequency data.

The output cards from Program FCON are prepared as input to Program TEMPF to yield cumulative frequency and cumulative probability data of the consolidated temperature data as discussed above.

All plotted data presented in this publication are augmented with tabulated data and are available in the permanent file of the NWC Ordnance Test and Evaluation Division.

DEFINITIONS OF DATA

Data presented in Figure B-4 are defined in the following:

TAPE NO. is the tape number identifying the tape that temperature data are written on.

FILE NO. is the file number of the tape that the data are written on.

IDENTIFICATION gives the type of magazine from which the data were obtained, the year of the data, the storage location, and the date the data were written on this tape.

MIN column gives the daily minimum temperature data.

MAX column gives the daily maximum temperature data.

TMIN TOTAL DATA PTS gives the total number of daily minimum temperature data available on this file.

TMAX TOTAL DATA PTS gives the total number of daily maximum temperature data available on this file.

NO. OF BAD PTS gives the number of daily minimum or maximum temperature data that were lower than -20°F or greater than 120°F.

IGLOOS SEATTLE, WASHINGTON

CUMULATIVE FREQUENCY UP TO (TMIN AND TMAX) SUB I

-20 DEG:	0	10 DEG:	0	40 DEG:	49	70 DEG:	622	100 DEG:	642
-19 DEG:	0	11 DEG:	0	41 DEG:	61	71 DEG:	622	101 DEG:	642
-18 DEG:	0	12 DEG:	0	42 DEG:	78	72 DEG:	628	102 DEG:	642
-17 DEG:	0	13 DEG:	0	43 DEG:	111	73 DEG:	630	103 DEG:	642
-16 DEG:	0	14 DEG:	0	44 DEG:	139	74 DEG:	630	104 DEG:	642
-15 DEG:	0	15 DEG:	0	45 DEG:	178	75 DEG:	635	105 DEG:	642
-14 DEG:	0	16 DEG:	0	46 DEG:	210	76 DEG:	640	106 DEG:	642
-13 DEG:	0	17 DEG:	0	47 DEG:	240	77 DEG:	640	107 DEG:	642
-12 DEG:	0	18 DEG:	0	48 DEG:	263	78 DEG:	640	108 DEG:	642
-11 DEG:	0	19 DEG:	0	49 DEG:	273	79 DEG:	642	109 DEG:	642
-10 DEG:	0	20 DEG:	0	50 DEG:	319	80 DEG:	642	110 DEG:	642
-9 DEG:	0	21 DEG:	0	51 DEG:	346	81 DEG:	642	111 DEG:	642
-8 DEG:	0	22 DEG:	0	52 DEG:	358	82 DEG:	642	112 DEG:	642
-7 DEG:	0	23 DEG:	0	53 DEG:	368	83 DEG:	642	113 DEG:	642
-6 DEG:	0	24 DEG:	0	54 DEG:	383	84 DEG:	642	114 DEG:	642
-5 DEG:	0	25 DEG:	0	55 DEG:	408	85 DEG:	642	115 DEG:	642
-4 DEG:	0	26 DEG:	0	56 DEG:	430	86 DEG:	642	116 DEG:	642
-3 DEG:	0	27 DEG:	0	57 DEG:	446	87 DEG:	642	117 DEG:	642
-2 DEG:	0	28 DEG:	0	58 DEG:	465	88 DEG:	642	118 DEG:	642
-1 DEG:	0	29 DEG:	0	59 DEG:	472	89 DEG:	642	119 DEG:	642
0 DEG:	0	30 DEG:	0	60 DEG:	503	90 DEG:	642	120 DEG:	642
1 DEG:	0	31 DEG:	1	61 DEG:	513	91 DEG:	642		
2 DEG:	0	32 DEG:	2	62 DEG:	531	92 DEG:	642		
3 DEG:	0	33 DEG:	2	63 DEG:	547	93 DEG:	642		
4 DEG:	0	34 DEG:	2	64 DEG:	561	94 DEG:	642		
5 DEG:	0	35 DEG:	4	65 DEG:	584	95 DEG:	642		
6 DEG:	0	36 DEG:	8	66 DEG:	596	96 DEG:	642		
7 DEG:	0	37 DEG:	13	67 DEG:	601	97 DEG:	642		
8 DEG:	0	38 DEG:	17	68 DEG:	612	98 DEG:	642		
9 DEG:	0	39 DEG:	23	69 DEG:	615	99 DEG:	642		

FIGURE B-5.

CUMULATIVE PROBABILITY UP TO (TMIN AND TMAX) SUB 1

-20 DEG:	.0000	10 DEG:	.0000	40 DEG:	.0763	70 DEG:	.9688	100 DEG:	1.0000
-19 DEG:	.0000	11 DEG:	.0000	41 DEG:	.0950	71 DEG:	.9688	101 DEG:	1.0000
-18 DEG:	.0000	12 DEG:	.0000	42 DEG:	.1215	72 DEG:	.9782	102 DEG:	1.0000
-17 DEG:	.0000	13 DEG:	.0000	43 DEG:	.1729	73 DEG:	.9813	103 DEG:	1.0000
-16 DEG:	.0000	14 DEG:	.0000	44 DEG:	.2165	74 DEG:	.9813	104 DEG:	1.0000
-15 DEG:	.0000	15 DEG:	.0000	45 DEG:	.2773	75 DEG:	.9891	105 DEG:	1.0000
-14 DEG:	.0000	16 DEG:	.0000	46 DEG:	.3271	76 DEG:	.9969	106 DEG:	1.0000
-13 DEG:	.0000	17 DEG:	.0000	47 DEG:	.3738	77 DEG:	.9969	107 DEG:	1.0000
-12 DEG:	.0000	18 DEG:	.0000	48 DEG:	.4097	78 DEG:	.9969	108 DEG:	1.0000
-11 DEG:	.0000	19 DEG:	.0000	49 DEG:	.4252	79 DEG:	1.0000	109 DEG:	1.0000
-10 DEG:	.0000	20 DEG:	.0000	50 DEG:	.4969	80 DEG:	1.0000	110 DEG:	1.0000
-9 DEG:	.0000	21 DEG:	.0000	51 DEG:	.5389	81 DEG:	1.0000	111 DEG:	1.0000
-8 DEG:	.0000	22 DEG:	.0000	52 DEG:	.5576	82 DEG:	1.0000	112 DEG:	1.0000
-7 DEG:	.0000	23 DEG:	.0000	53 DEG:	.5732	83 DEG:	1.0000	113 DEG:	1.0000
-6 DEG:	.0000	24 DEG:	.0000	54 DEG:	.5966	84 DEG:	1.0000	114 DEG:	1.0000
-5 DEG:	.0000	25 DEG:	.0000	55 DEG:	.6355	85 DEG:	1.0000	115 DEG:	1.0000
-4 DEG:	.0000	26 DEG:	.0000	56 DEG:	.6698	86 DEG:	1.0000	116 DEG:	1.0000
-3 DEG:	.0000	27 DEG:	.0000	57 DEG:	.6947	87 DEG:	1.0000	117 DEG:	1.0000
-2 DEG:	.0000	28 DEG:	.0000	58 DEG:	.7243	88 DEG:	1.0000	118 DEG:	1.0000
-1 DEG:	.0000	29 DEG:	.0000	59 DEG:	.7352	89 DEG:	1.0000	119 DEG:	1.0000
0 DEG:	.0000	30 DEG:	.0000	60 DEG:	.7835	90 DEG:	1.0000	120 DEG:	1.0000
1 DEG:	.0000	31 DEG:	.0016	61 DEG:	.7991	91 DEG:	1.0000		
2 DEG:	.0000	32 DEG:	.0031	62 DEG:	.8271	92 DEG:	1.0000		
3 DEG:	.0000	33 DEG:	.0031	63 DEG:	.8520	93 DEG:	1.0000		
4 DEG:	.0000	34 DEG:	.0031	64 DEG:	.8738	94 DEG:	1.0000		
5 DEG:	.0000	35 DEG:	.0062	65 DEG:	.9097	95 DEG:	1.0000		
6 DEG:	.0000	36 DEG:	.0125	66 DEG:	.9283	96 DEG:	1.0000		
7 DEG:	.0000	37 DEG:	.0202	67 DEG:	.9361	97 DEG:	1.0000		
8 DEG:	.0000	38 DEG:	.0265	68 DEG:	.9533	98 DEG:	1.0000		
9 DEG:	.0000	39 DEG:	.0358	69 DEG:	.9579	99 DEG:	1.0000		

FIGURE B-5. (Contd.)

IGLOO5 SEATTLE, WASHINGTON

PROBABILITY OF (TMIN AND TMAX) SUB I

-20 DEG: .0000	10 DEG: .0000	40 DEG: .0405	70 DEG: .0109	100 DEG: .0000
-19 DEG: .0000	11 DEG: .0000	41 DEG: .0187	71 DEG: .0000	101 DEG: .0000
-18 DEG: .0000	12 DEG: .0000	42 DEG: .0265	72 DEG: .0093	102 DEG: .0000
-17 DEG: .0000	13 DEG: .0000	43 DEG: .0514	73 DEG: .0031	103 DEG: .0000
-16 DEG: .0000	14 DEG: .0000	44 DEG: .0436	74 DEG: .0000	104 DEG: .0000
-15 DEG: .0000	15 DEG: .0000	45 DEG: .0607	75 DEG: .0078	105 DEG: .0000
-14 DEG: .0000	16 DEG: .0000	46 DEG: .0498	76 DEG: .0078	106 DEG: .0000
-13 DEG: .0000	17 DEG: .0000	47 DEG: .0467	77 DEG: .0000	107 DEG: .0000
-12 DEG: .0000	18 DEG: .0000	48 DEG: .0358	78 DEG: .0000	108 DEG: .0000
-11 DEG: .0000	19 DEG: .0000	49 DEG: .0156	79 DEG: .0031	109 DEG: .0000
-10 DEG: .0000	20 DEG: .0000	50 DEG: .0717	80 DEG: .0000	110 DEG: .0000
-9 DEG: .0000	21 DEG: .0000	51 DEG: .0421	81 DEG: .0000	111 DEG: .0000
-8 DEG: .0000	22 DEG: .0000	52 DEG: .0187	82 DEG: .0000	112 DEG: .0000
-7 DEG: .0000	23 DEG: .0000	53 DEG: .0156	83 DEG: .0000	113 DEG: .0000
-6 DEG: .0000	24 DEG: .0000	54 DEG: .0234	84 DEG: .0000	114 DEG: .0000
-5 DEG: .0000	25 DEG: .0000	55 DEG: .0389	85 DEG: .0000	115 DEG: .0000
-4 DEG: .0000	26 DEG: .0000	56 DEG: .0343	86 DEG: .0000	116 DEG: .0000
-3 DEG: .0000	27 DEG: .0000	57 DEG: .0249	87 DEG: .0000	117 DEG: .0000
-2 DEG: .0000	28 DEG: .0000	58 DEG: .0296	88 DEG: .0000	118 DEG: .0000
-1 DEG: .0000	29 DEG: .0000	59 DEG: .0109	89 DEG: .0000	119 DEG: .0000
0 DEG: .0000	30 DEG: .0000	60 DEG: .0483	90 DEG: .0000	120 DEG: .0000
1 DEG: .0000	31 DEG: .0016	61 DEG: .0156	91 DEG: .0000	
2 DEG: .0000	32 DEG: .0016	62 DEG: .0280	92 DEG: .0000	
3 DEG: .0000	33 DEG: .0000	63 DEG: .0249	93 DEG: .0000	
4 DEG: .0000	34 DEG: .0000	64 DEG: .0218	94 DEG: .0000	
5 DEG: .0000	35 DEG: .0031	65 DEG: .0358	95 DEG: .0000	
6 DEG: .0000	36 DEG: .0062	66 DEG: .0187	96 DEG: .0000	
7 DEG: .0000	37 DEG: .0078	67 DEG: .0078	97 DEG: .0000	
8 DEG: .0000	38 DEG: .0062	68 DEG: .0171	98 DEG: .0000	
9 DEG: .0000	39 DEG: .0093	69 DEG: .0047	99 DEG: .0000	

FIGURE B-5. (Contd.)

NO. OF DATA PTS USED gives the number of daily minimum or maximum temperature data that were used in the compilation of the frequency data.

FREQUENCY OF TMIN SUB I gives the frequencies of the daily minimum temperature data from -20° to 120°F at 1-degree intervals and denoted $N_{t_{min_i}}$.

FREQUENCY OF TMAX SUB I gives the frequencies of the daily maximum temperature data from -20° to 120°F at 1-degree intervals and denoted $N_{t_{max_i}}$.

FREQUENCY OF (TMAX AND TMIN) SUB I gives the frequencies of the daily minimum and maximum, combined, temperature data from -20° to 120°F at 1-degree intervals and denoted $N\left(t_{min_i} \text{ and } t_{max_i}\right)$.

Data presented in Figure B-5 are defined in the following:

CUMULATIVE FREQUENCY UP TO TMIN SUB I gives the cumulative frequencies of the daily minimum temperature from -20°F up to minimum temperature of interest and denoted $NCF_{t_{min_i}}$.

$$NCF_{t_{min_i}} = \sum_{j}^{k} N_{t_{min_i}}$$

, where $N_{t_{min_j}}$ is the frequency of -20°F temperature and $N_{t_{min_k}}$ is the frequency of temperature of interest.

CUMULATIVE FREQUENCY UP TO TMAX SUB I denoted $NCF_{t_{max_i}}$ is defined as follows:

$$NCF_{t_{max_i}} = \sum_{j}^{k} N\left(t_{min_i} \text{ and } t_{max_i}\right)$$

PROBABILITY OF TMIN SUB I denoted $P\left(t_{max_i}\right)$ defined as follows:

$$P\left(t_{min_i}\right) = \frac{N_{t_{min_i}}}{N_{t_{min_{total}}}}$$

, where $N_{t_{min_{total}}}$ is the total number of daily minimum temperature data used.

PROBABILITY OF TMAX SUB I denoted $P\left(t_{max_i}\right)$ is defined as follows:

$$P\left(t_{max_i}\right) = \frac{N_{t_{max_i}}}{N_{t_{max_{total}}}}$$

PROBABILITY OF (TMIN AND TMAX) SUB I denoted $P\left(t_{min_i} \text{ and } t_{max_i}\right)$ is defined as follows:

$$P\left(t_{min_i} \text{ and } t_{max_i}\right) = \frac{N\left(t_{min_i} \text{ and } t_{max_i}\right)}{N_{t_{min_{total}}} + N_{t_{max_{total}}}}$$

CUMULATIVE PROBABILITY UP TO TMIN SUB I denoted $Pc\left(t_{min_i}\right)$ gives the cumulative probabilities of the daily minimum temperature from -20°F up to minimum temperature of interest. It is defined as follows:

$$Pc\left(t_{min_i}\right) = \sum_{j}^{k} \frac{N_{t_{min_i}}}{N_{t_{min_{total}}}}$$

CUMULATIVE PROBABILITY UP TO TMAX SUB I denoted $Pc\left(t_{max_i}\right)$ is defined as follows:

$$Pc\left(t_{max_i}\right) = \sum_{j}^{k} \frac{N_{t_{max_i}}}{N_{t_{max_{total}}}}$$

CUMULATIVE PROBABILITY UP TO (TMIN AND TMAX) SUB I denoted

$$Pc\left(t_{min_i} \text{ and } t_{max_i}\right) = \sum_{j}^{k} \frac{N\left(t_{min_i} \text{ and } t_{max_i}\right)}{N_{t_{min_{total}}} + N_{t_{max_{total}}}}$$

Appendix C

CUMULATIVE PROBABILITY GRAPHS

The following graphs (Figures C-1 through C-42) are the individual cumulative probability graphs for the selected twenty-eight locations. Except for the Australian sites, each location is arranged first according to type of storage (igloos or above-ground storehouses) then according to the climatic zone (tropical, dry, humid mesothermal, humid microthermal).

The graphs for the individual Australian sites (Figures C-39 through C-42) combine the data for both types of storage. Additionally, Figures C-43 provides a consolidated graph for the various climatic zones found in Australia based on the individual sites data.

Keep in mind that the more data are available for each location, the smoother and more vertical become the graphs; the less data are available, the more horizontal the graph will become. Abruptness can be attributed to a lack of data.

Individual graphs

Igloos

1. Guantanamo Bay, Cuba
2. Agana, Guam
3. Oahu, Hawaii
4. Roosevelt Roads, Puerto Rico
5. Subic Bay, Republic of the Philippines
6. China Lake, California
7. Hawthorne, Nevada
8. Yuma, Arizona
9. Charleston, South Carolina
10. Corpus Christi, Texas
11. Keflavik, Iceland
12. McAlester, Oklahoma
13. Messina, Sicily
14. Naval Station, Bermuda
15. Seal Beach, California
16. Seattle, Washington
17. Wiesau, Germany
18. Adak, Alaska
19. Agentia, Newfoundland
20. Brunswick, Maine
21. Crane, Indiana
22. Kodiak, Alaska

Above-ground Storehouses

23. Agana, Guam
24. Guantanamo Bay, Cuba
25. Roosevelt Roads, Puerto Rico
26. Dallas, Texas
27. Yuma, Arizona
28. Kodiak, Alaska
29. Brunswick, Maine
30. Adak, Alaska
31. Wiesau, Germany
32. Seattle, Washington
33. Seal Beach, California
34. Naval Station, Bermuda
35. Messina, Sicily
36. Keflavik, Iceland
37. Corpus Christi, Texas
38. Atsugi, Japan

Consolidated Igloos/Above-ground Storehouses

39. East Sale, Australia
40. Darwin, Australia
41. Kingswood, Australia
42. Amberly, Australia

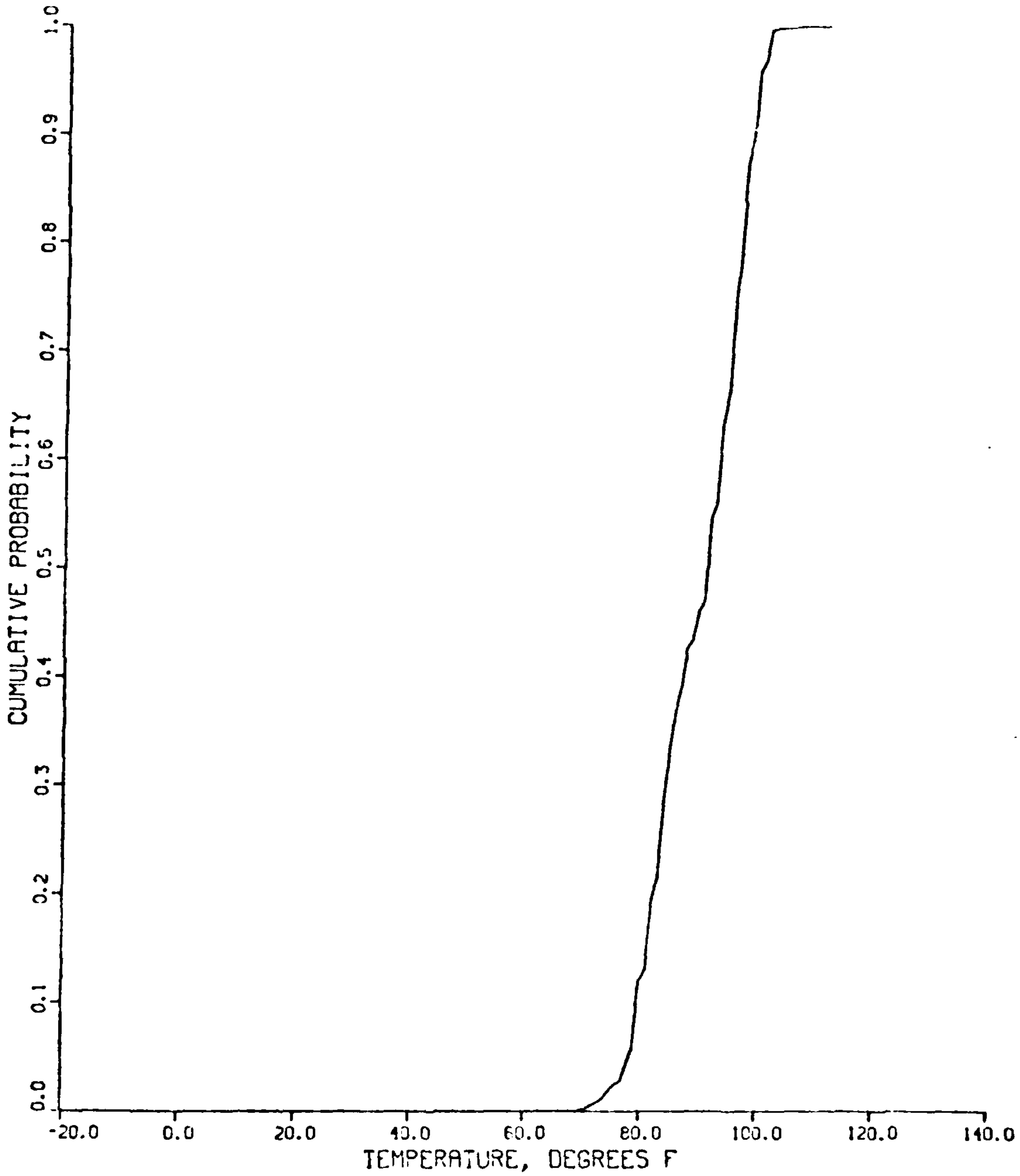

FIGURE C-1. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Guantanamo Bay, Cuba.

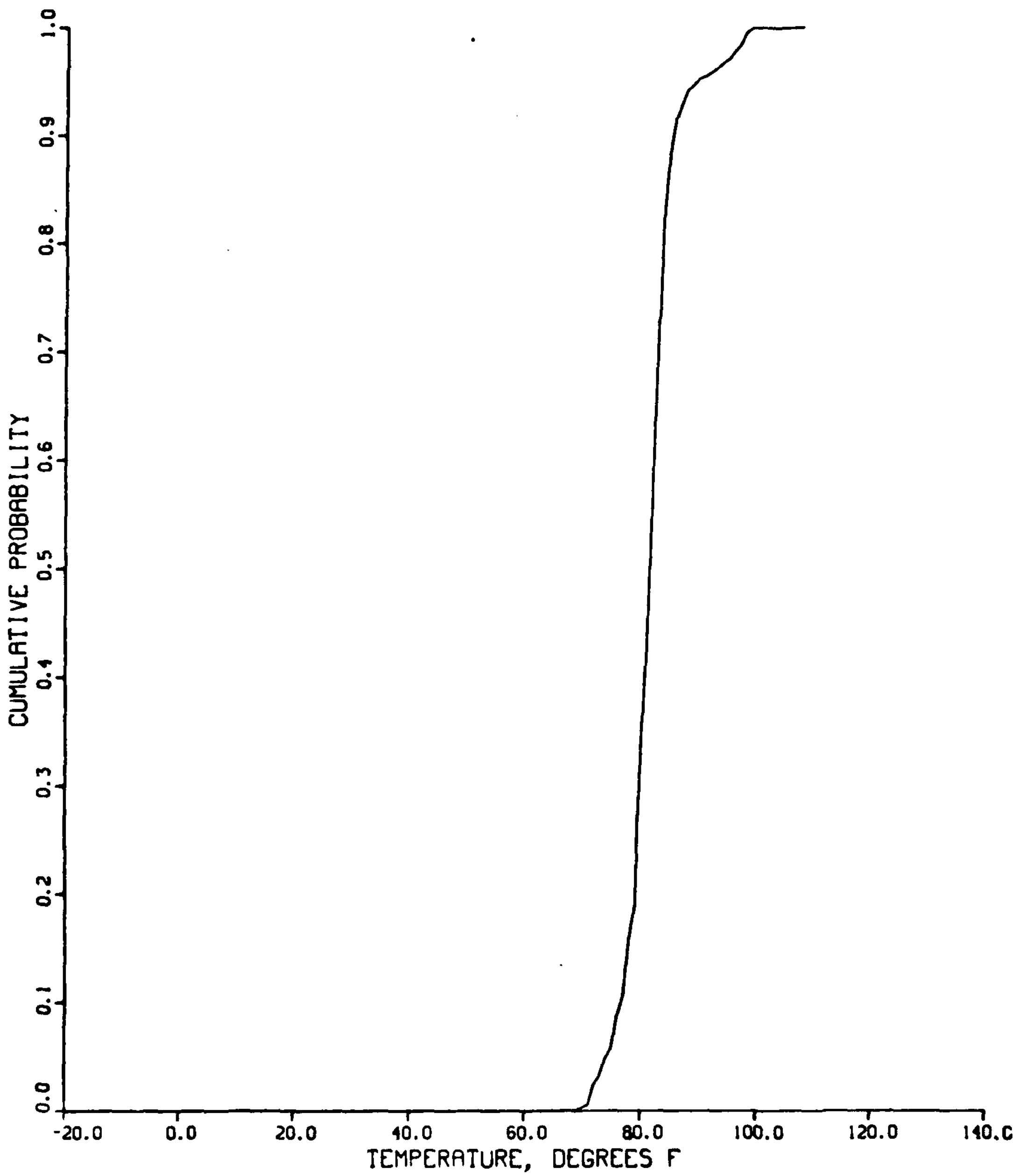

FIGURE C-2. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Agana, Guam

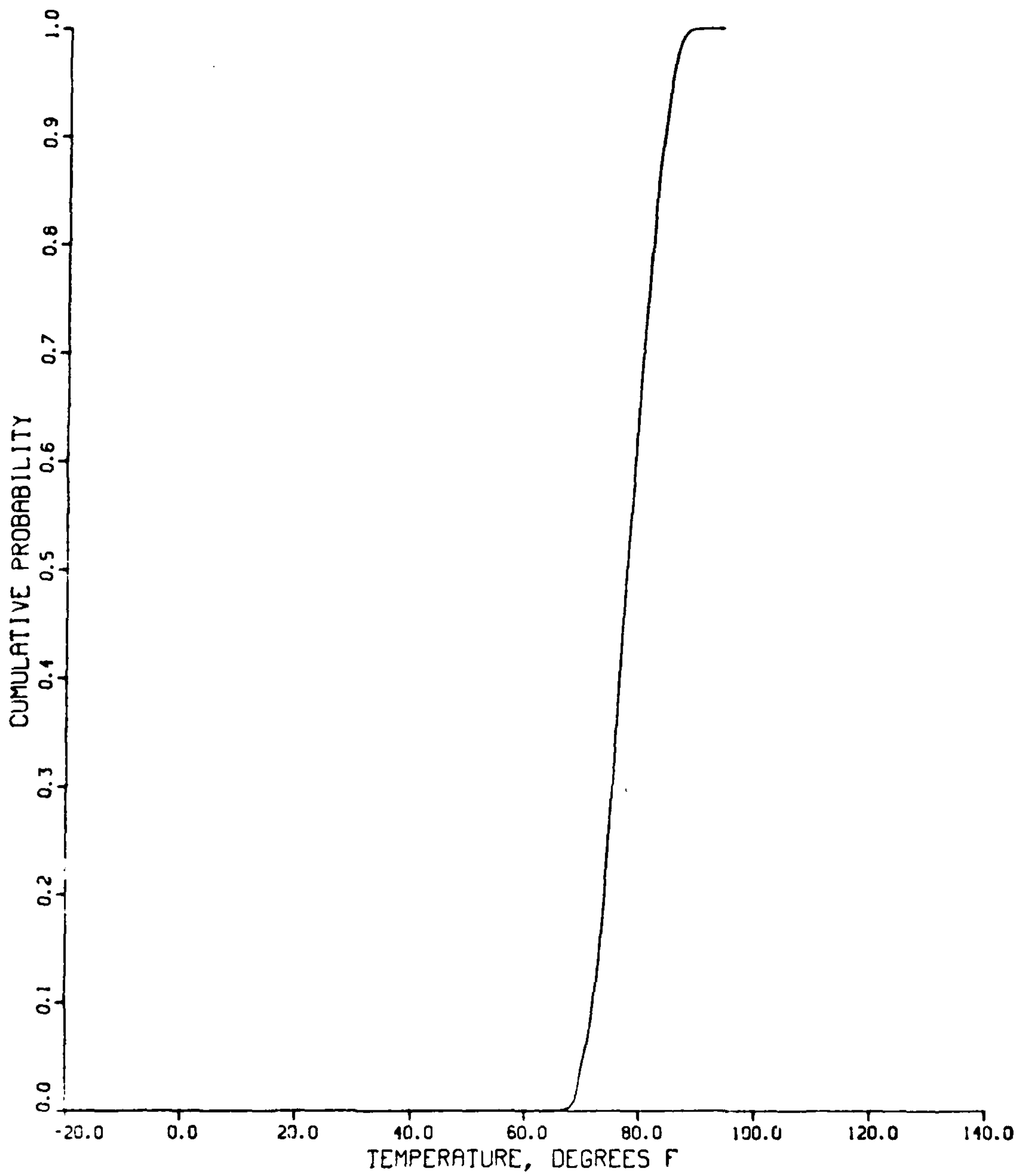

FIGURE C-3. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Oahu, Hawaii.

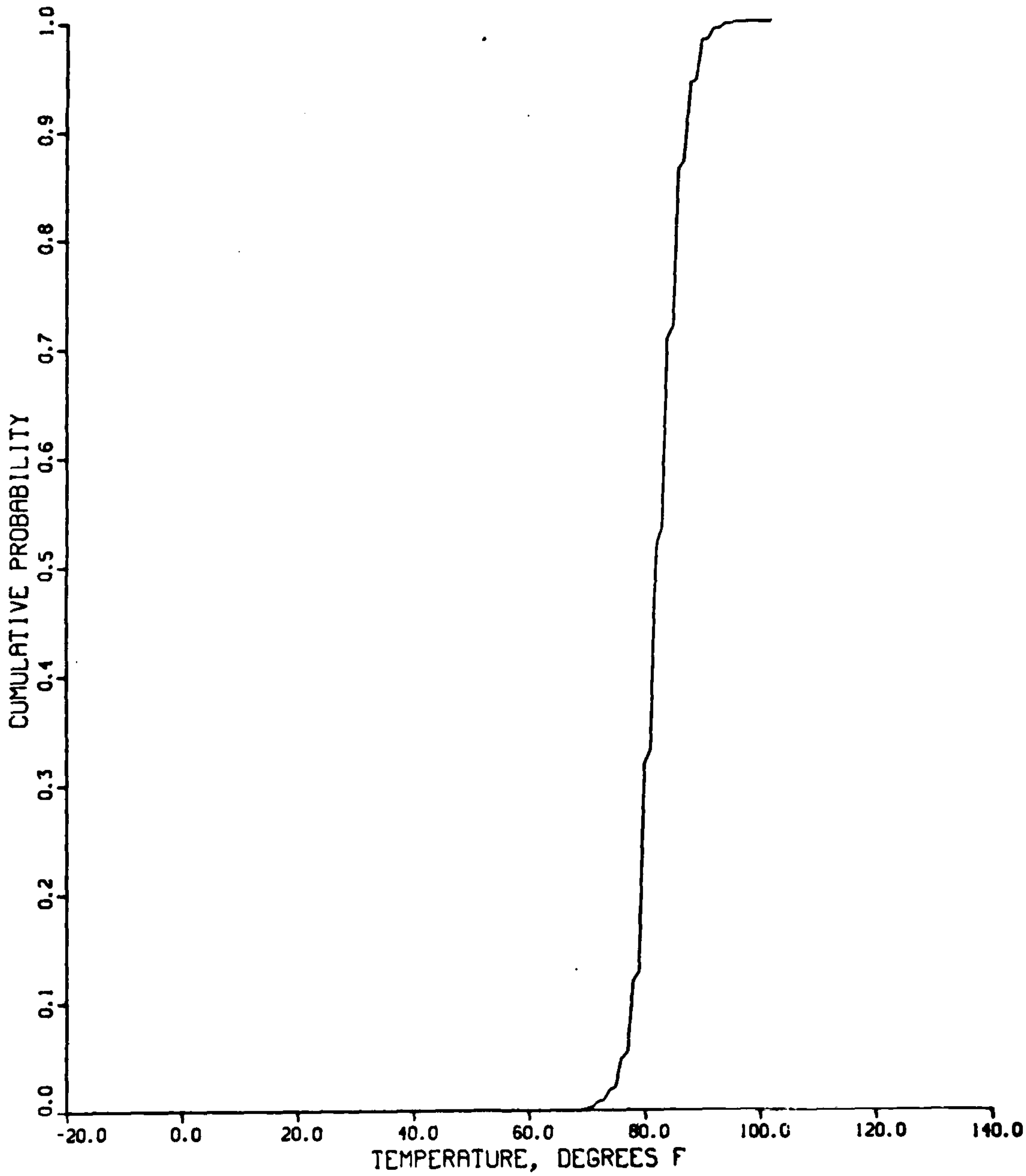

FIGURE C-4. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Roosevelt Roads, Puerto Rico.

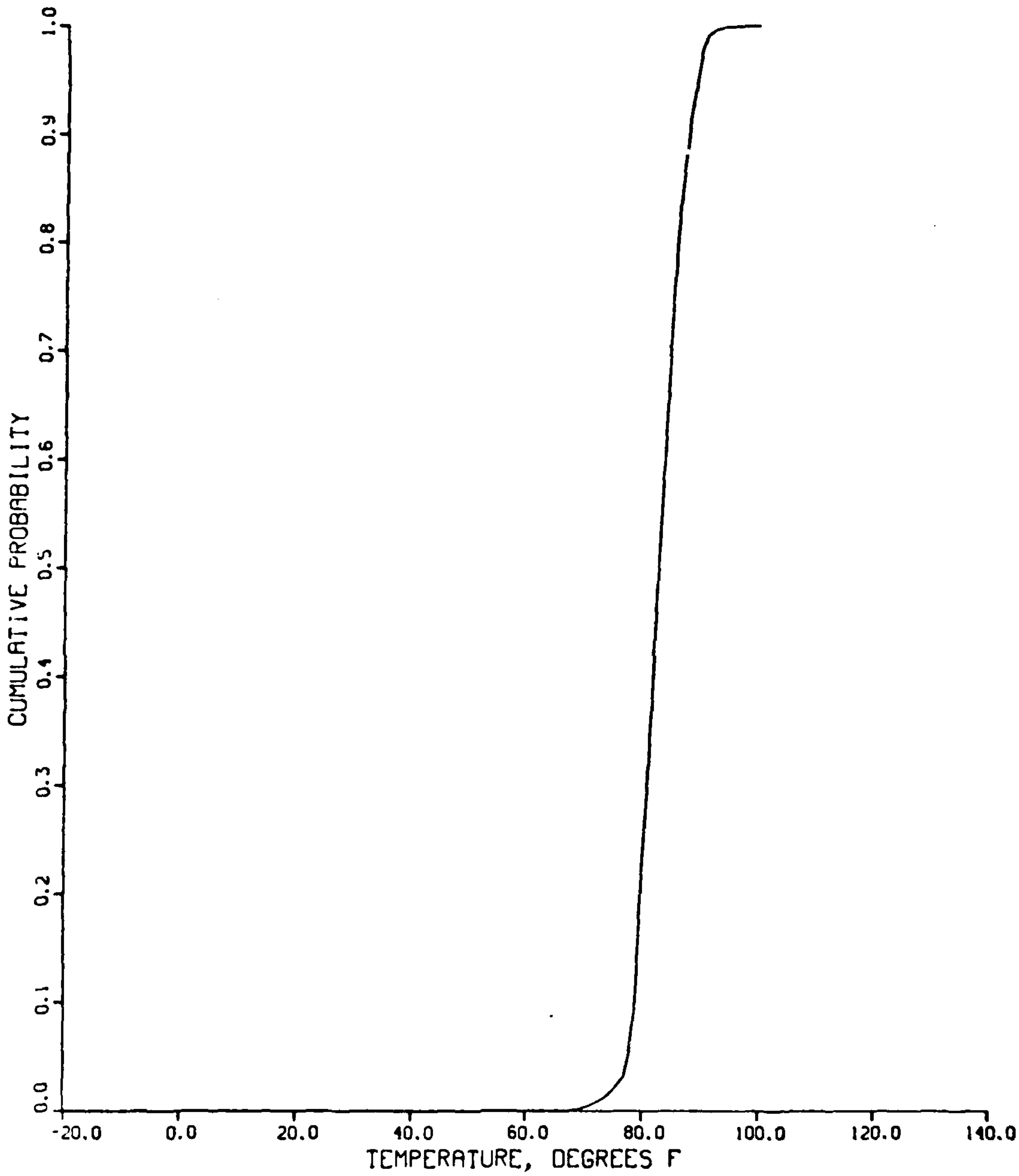

FIGURE C-5. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Republic of the Philippines.

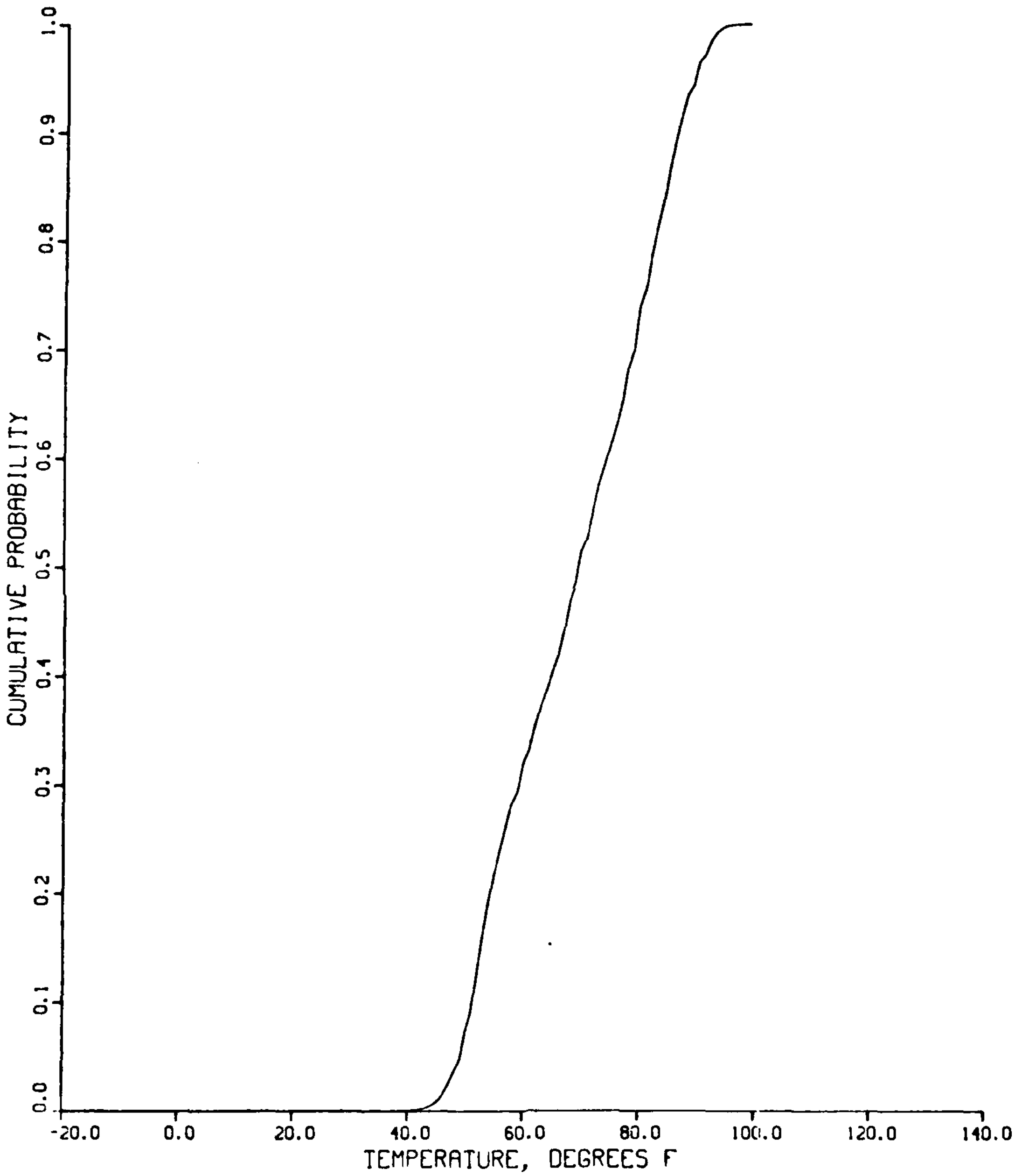

FIGURE C-6. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- China Lake, California.

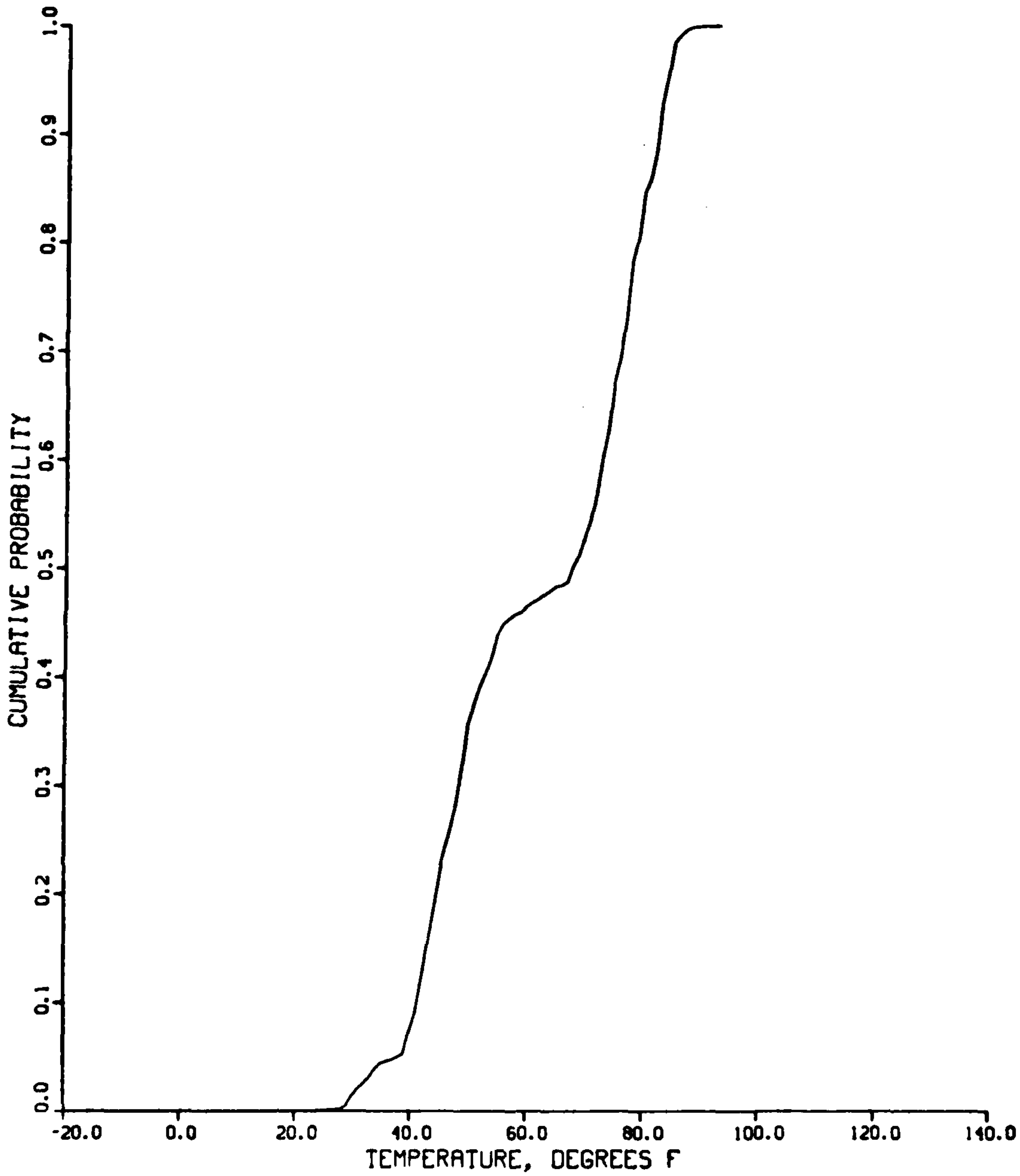

FIGURE C-7. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Hawthorne, Nevada.

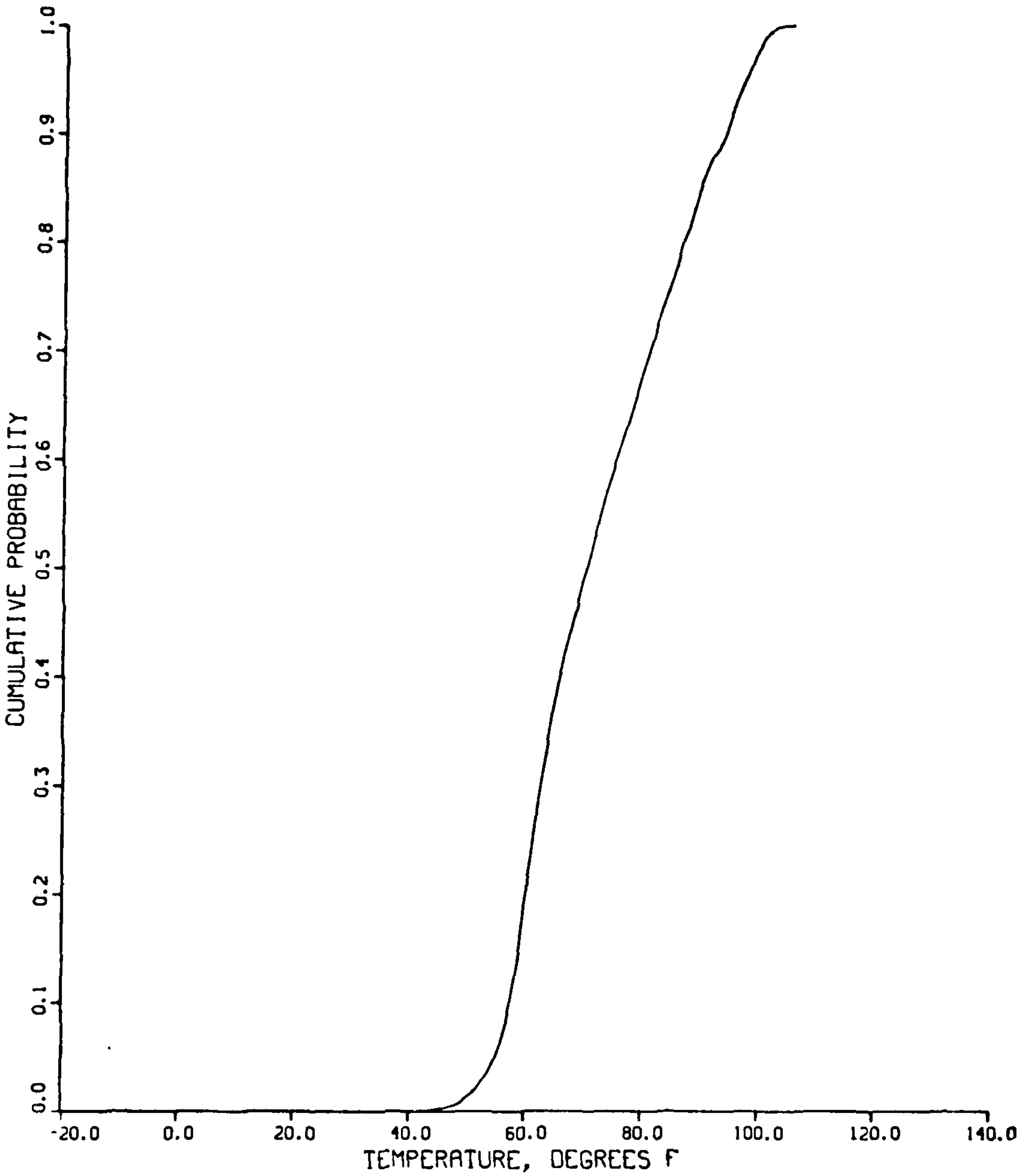

FIGURE C-8. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Yuma, Arizona.

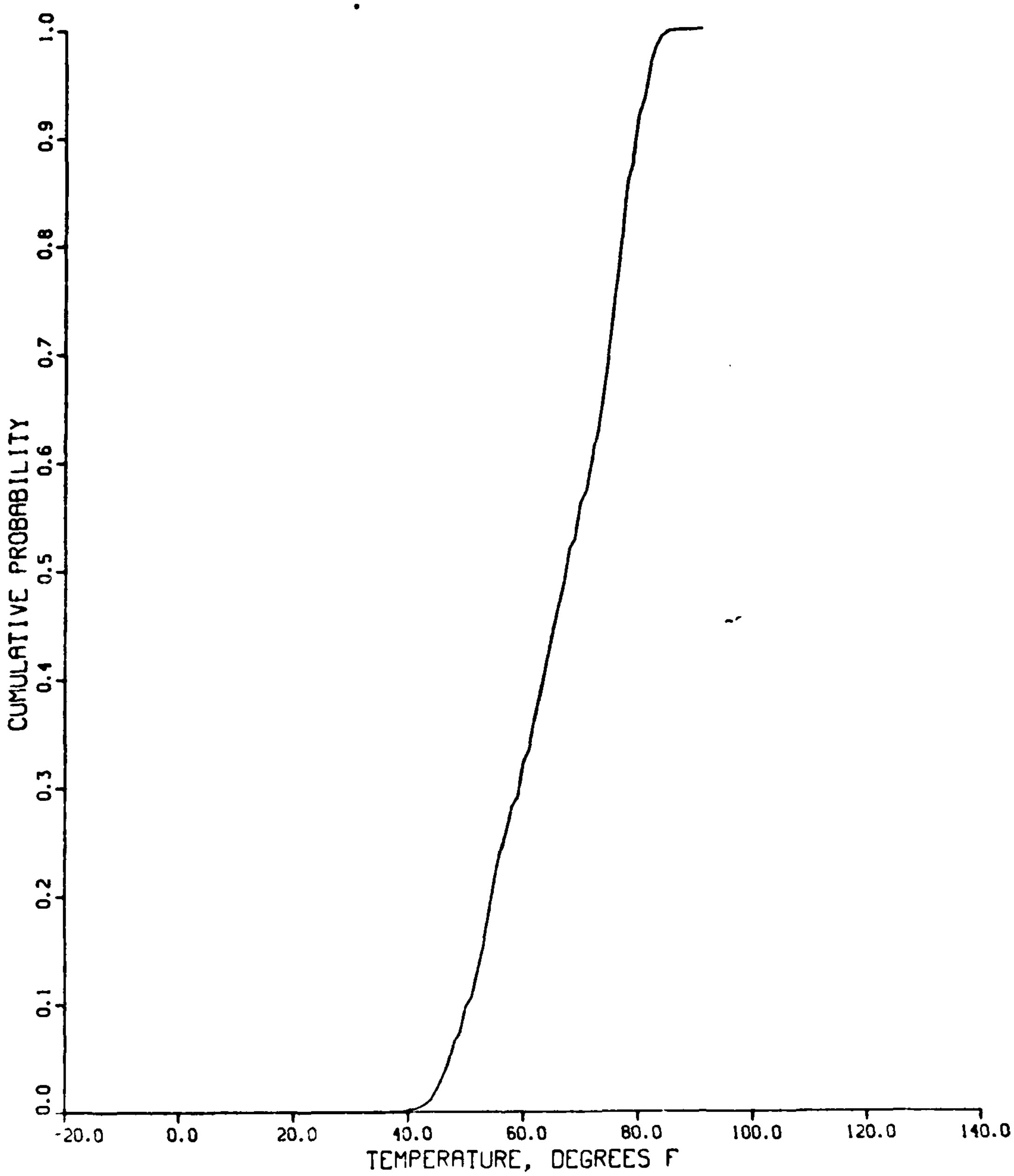

FIGURE C-9. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Charleston, South Carolina.

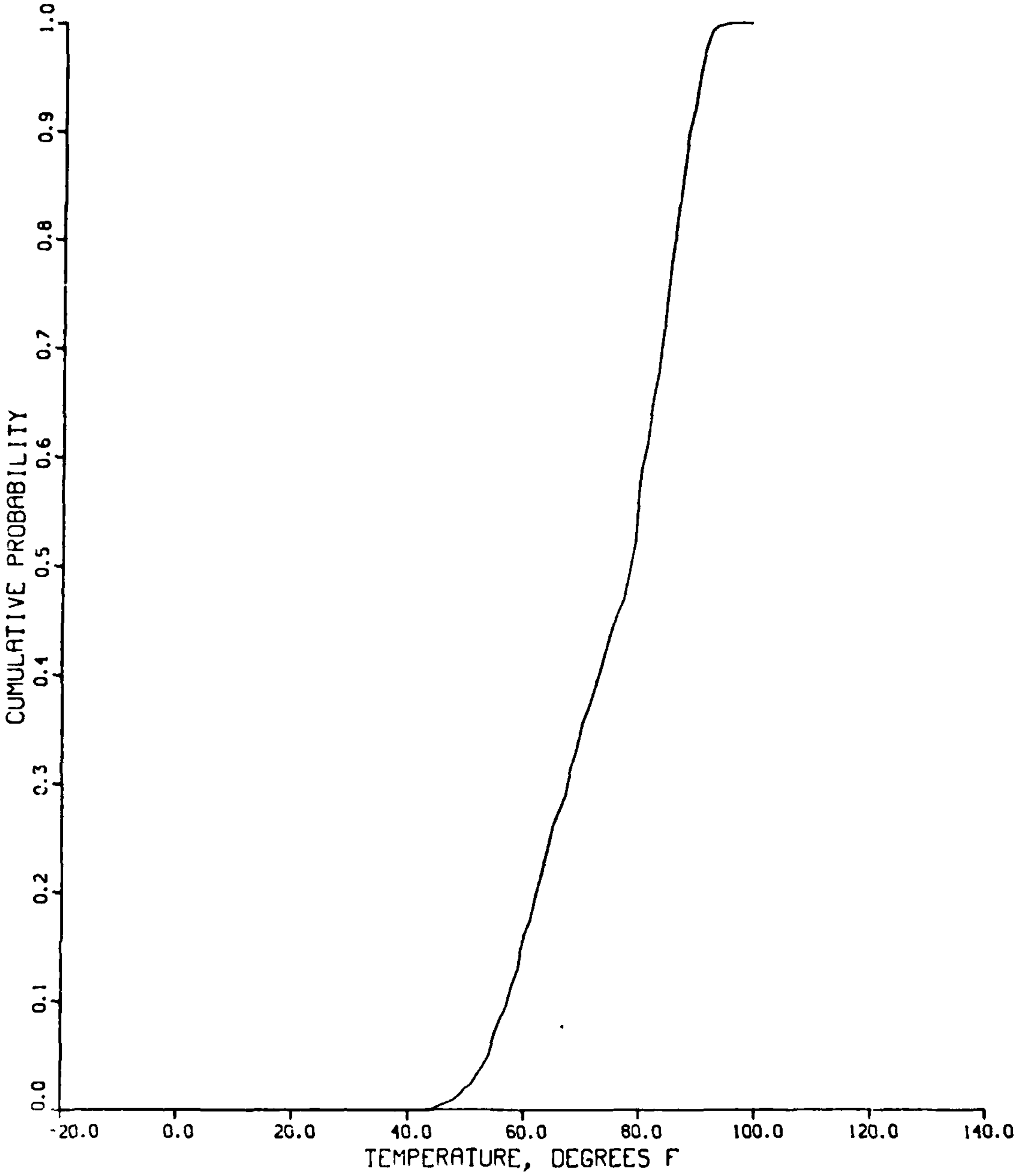

FIGURE C-10. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Corpus Christi, Texas.

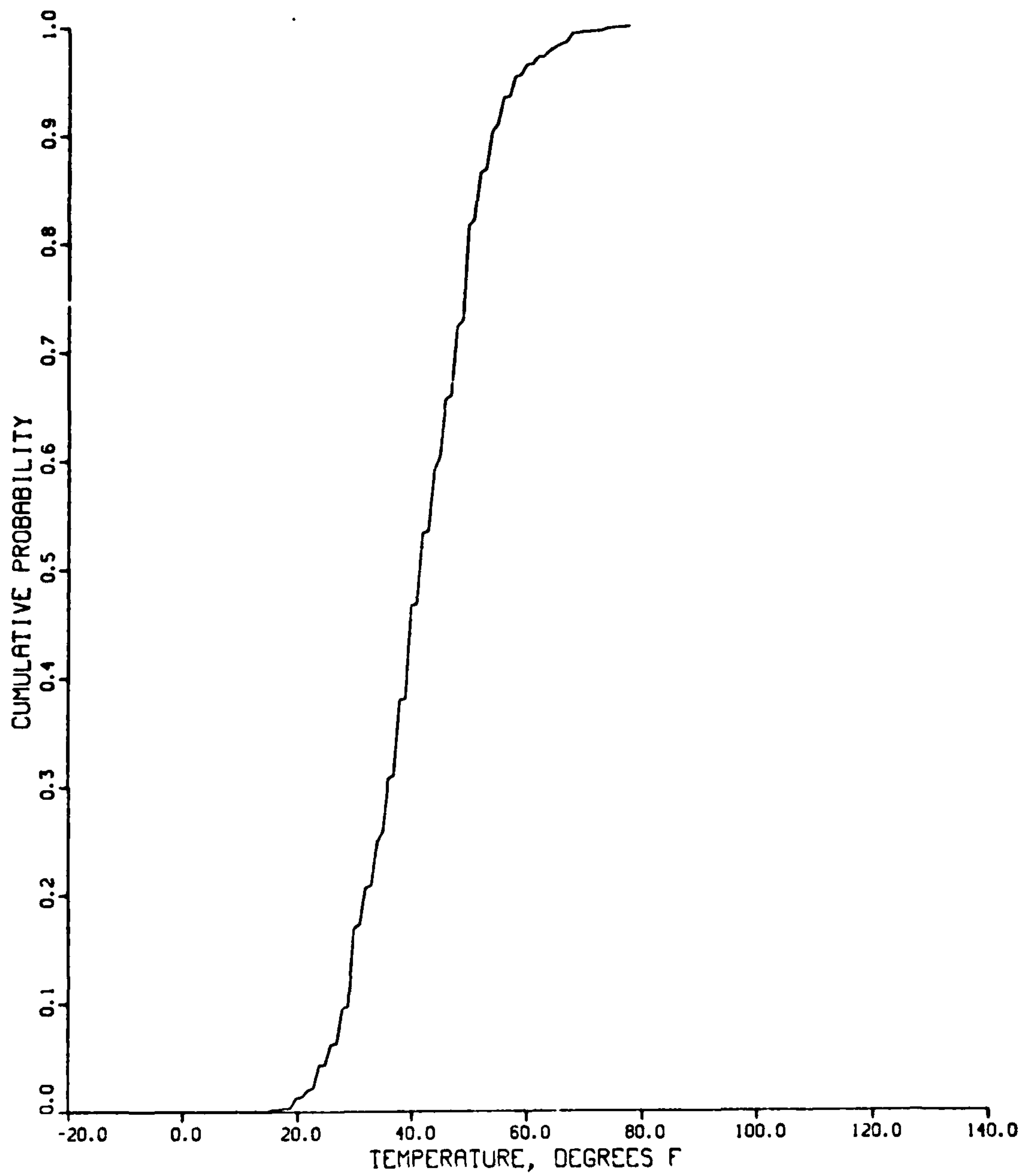

FIGURE C-11. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Keflavik, Iceland.

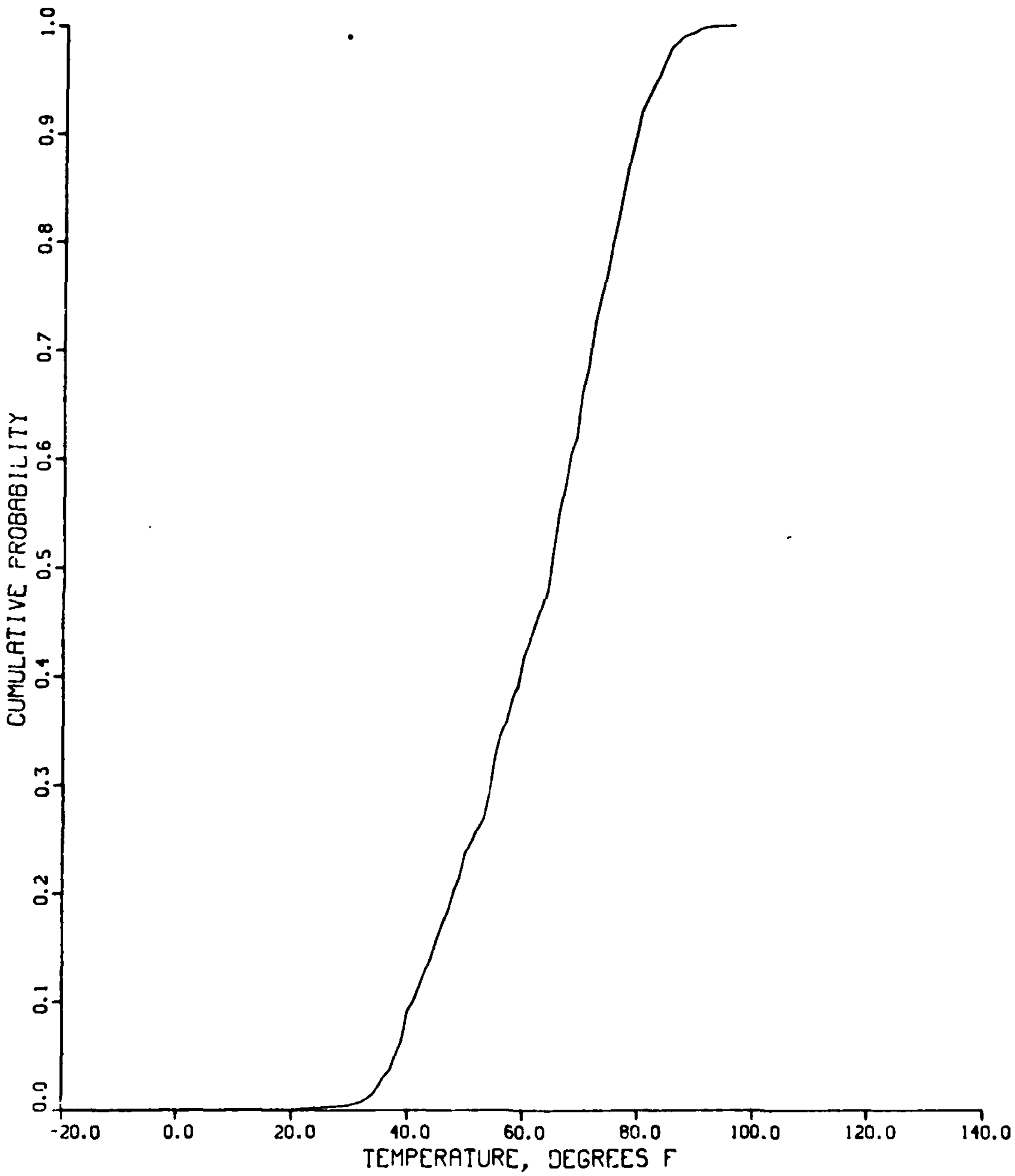

FIGURE C-12. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- McAlester, Oklahoma.

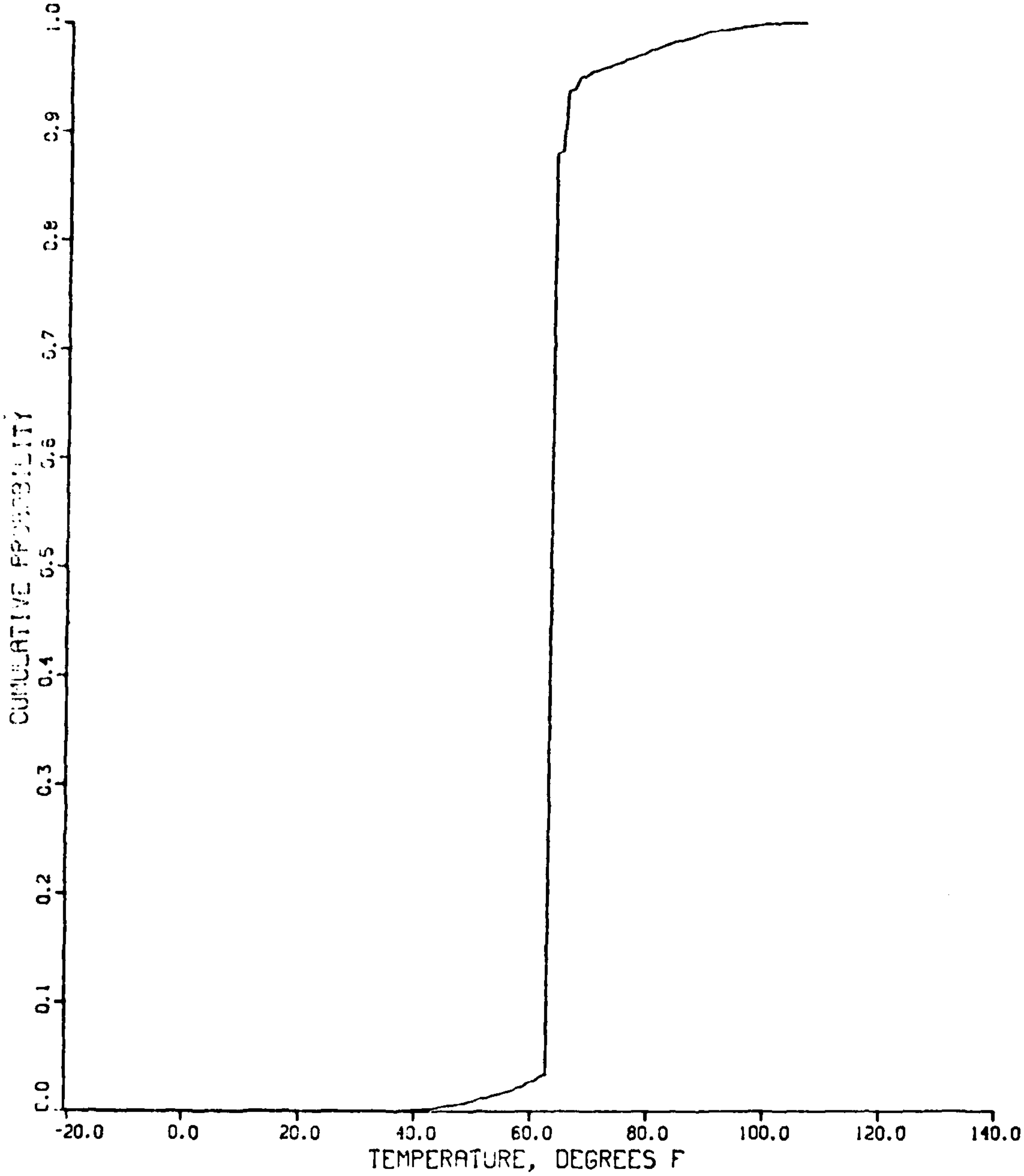

FIGURE C-13. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Messina, Sicily.

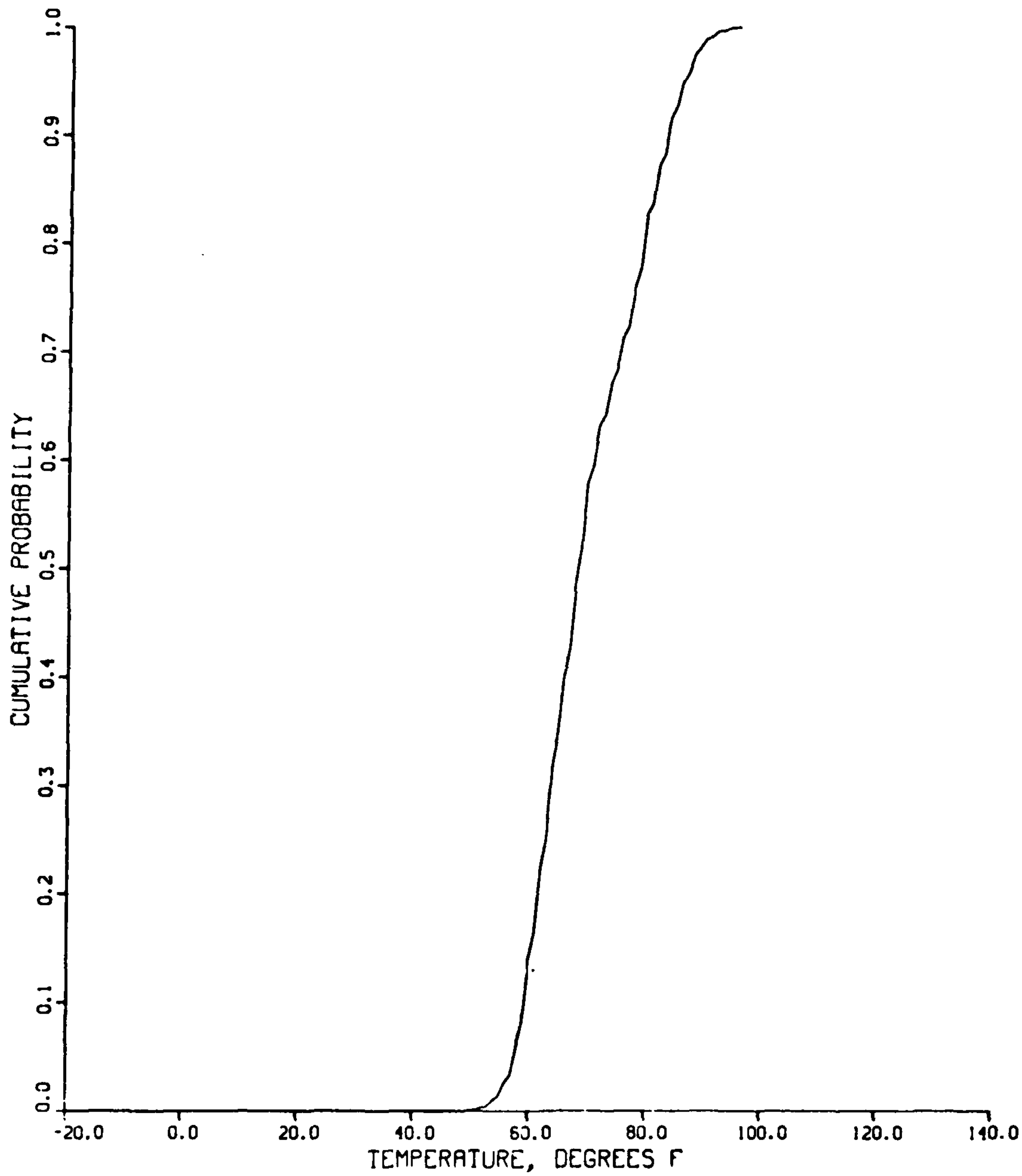

FIGURE C-14. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Naval Station, Bermuda.

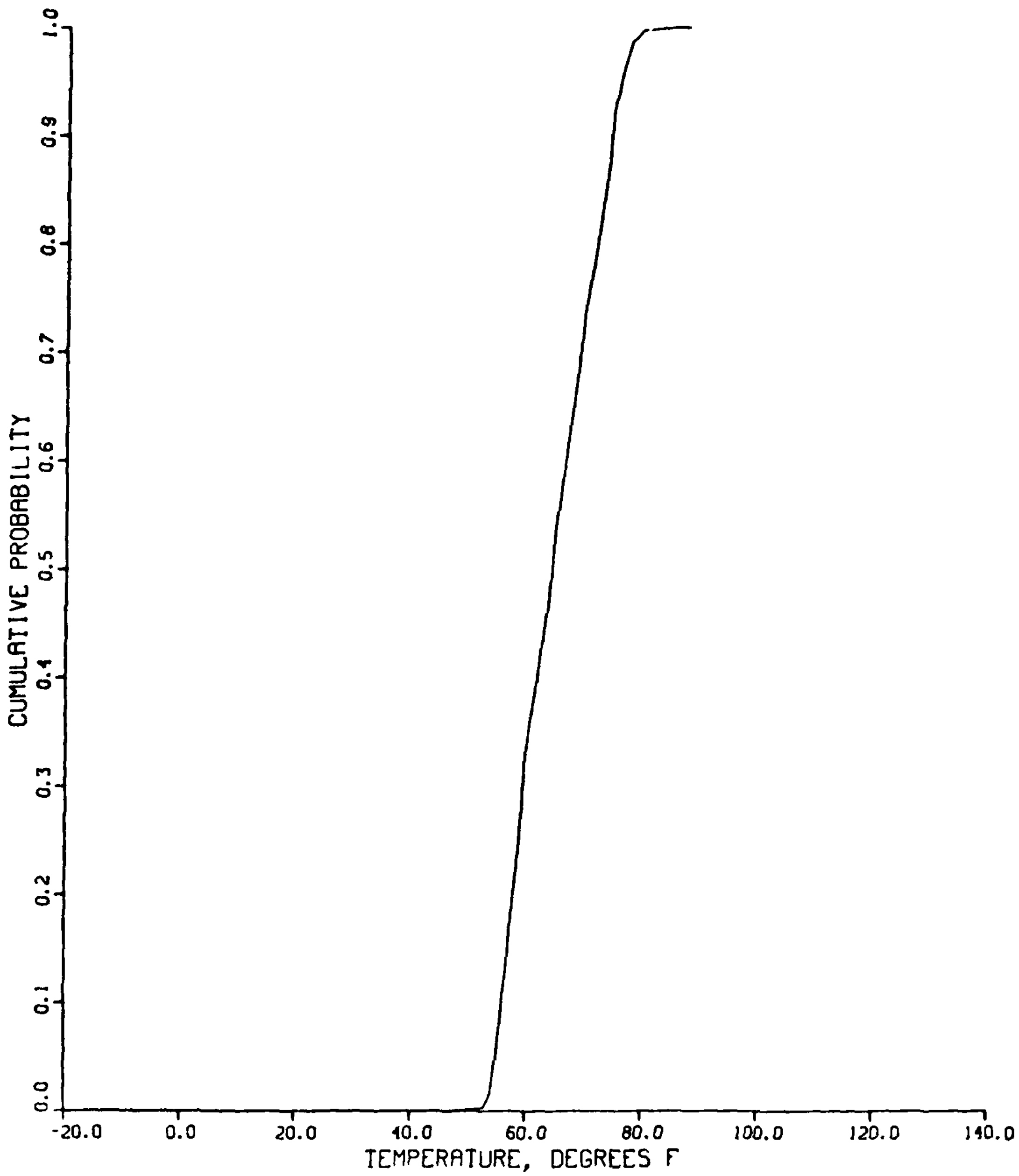

FIGURE C-15. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Seal Beach, California.

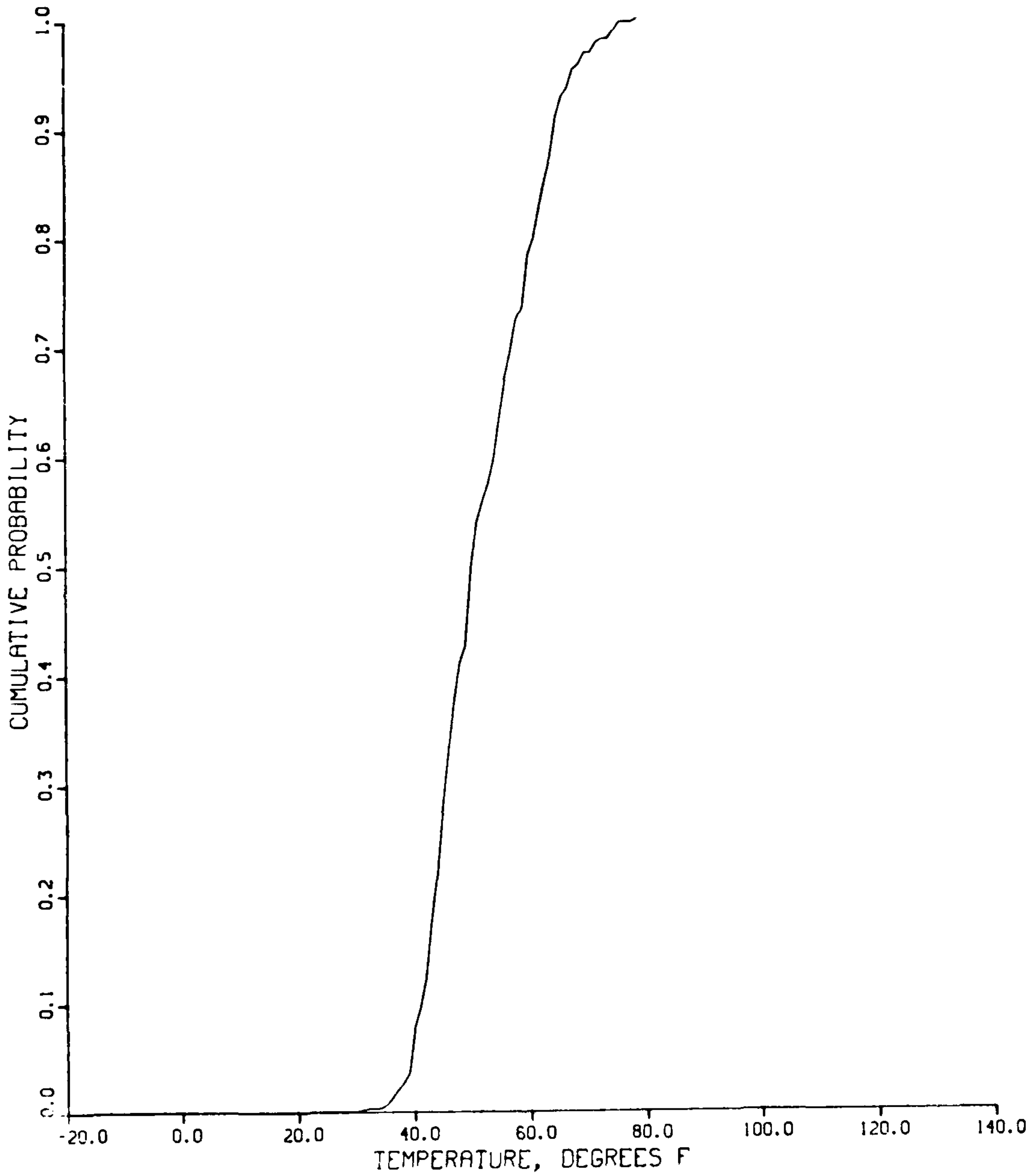

FIGURE C-16. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Seattle, Washington.

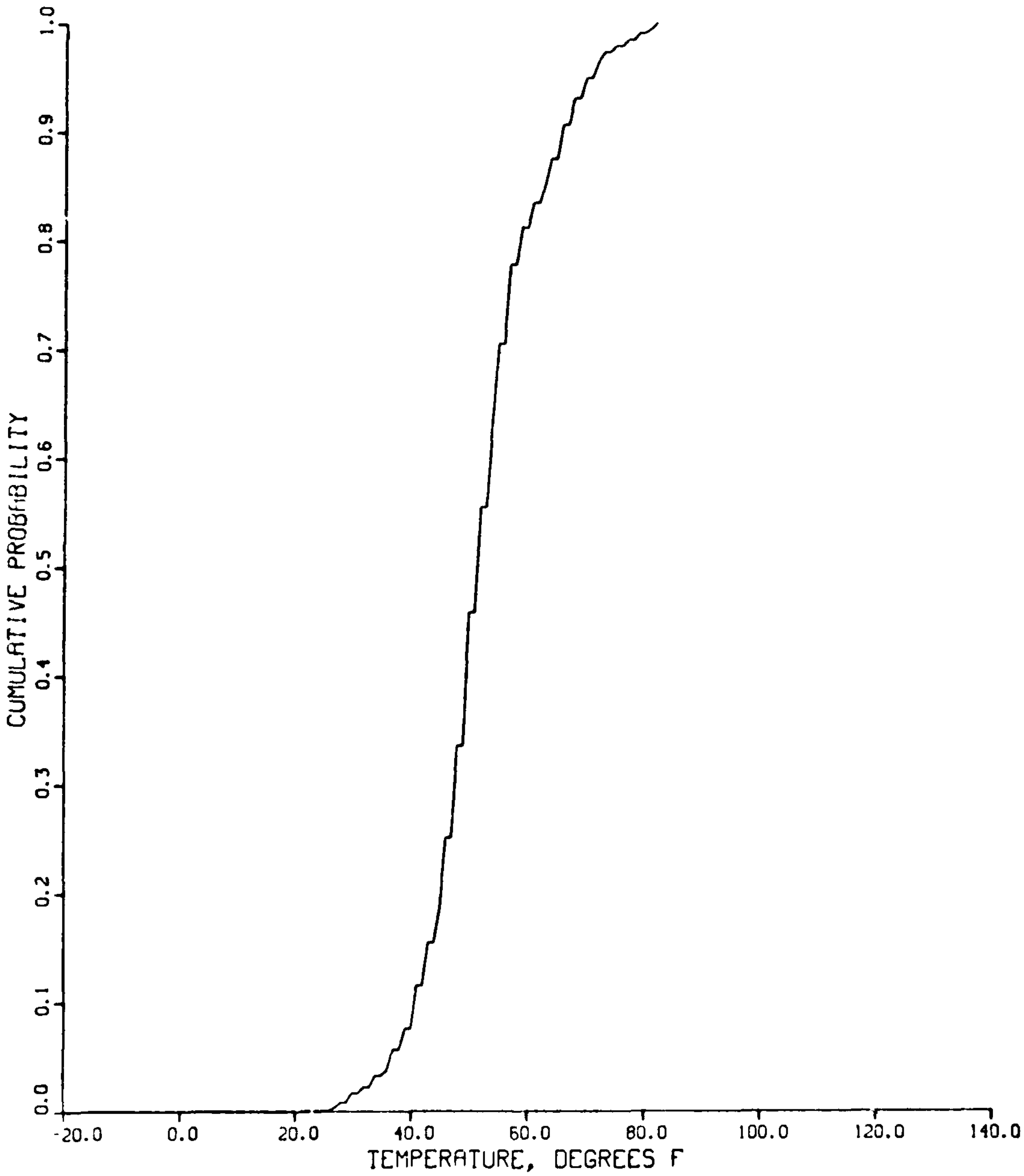

FIGURE C-17. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Wiesau, Germany.

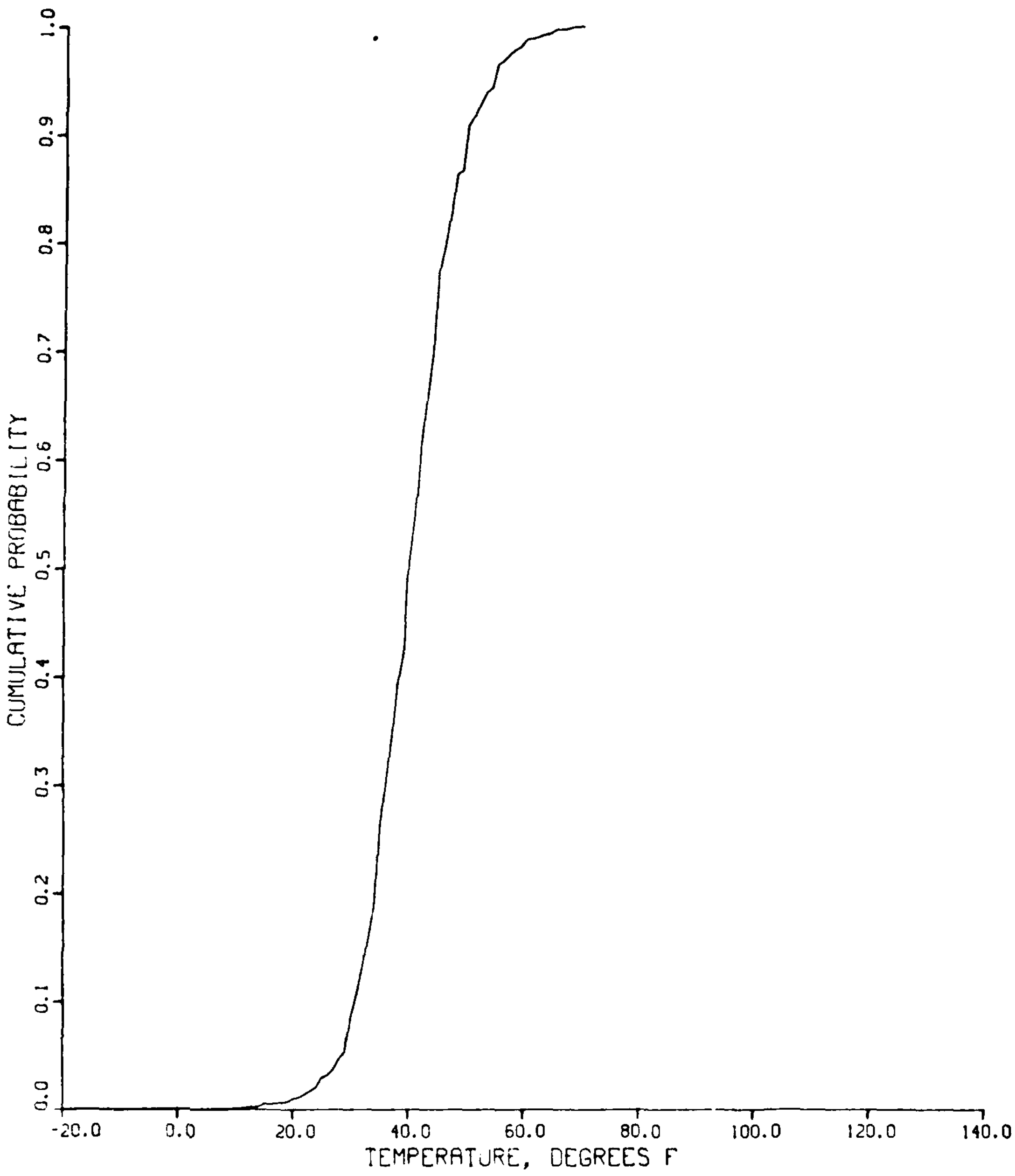

FIGURE C-18. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Adak, Alaska.

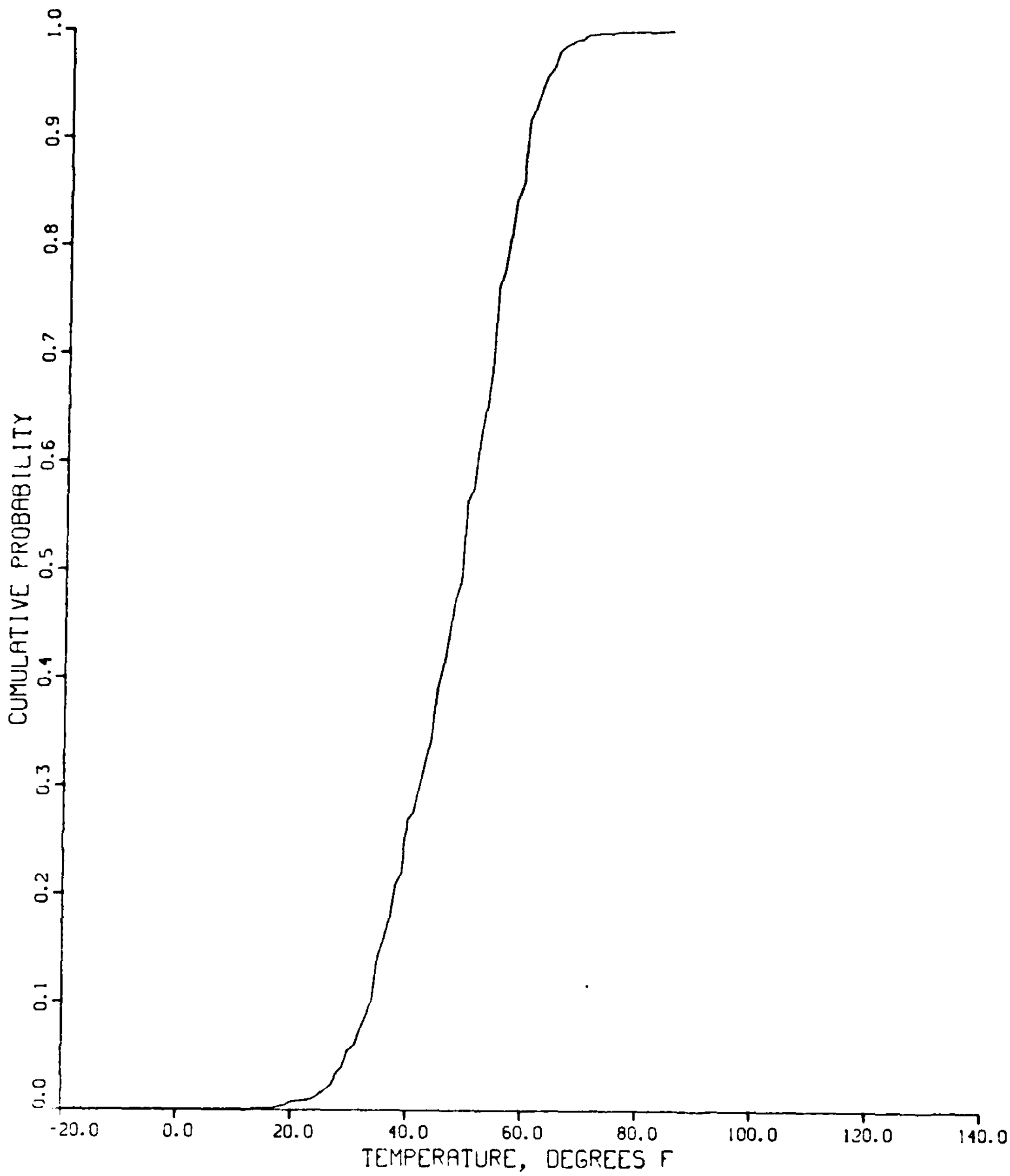

FIGURE C-19. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Argentia, Newfoundland.

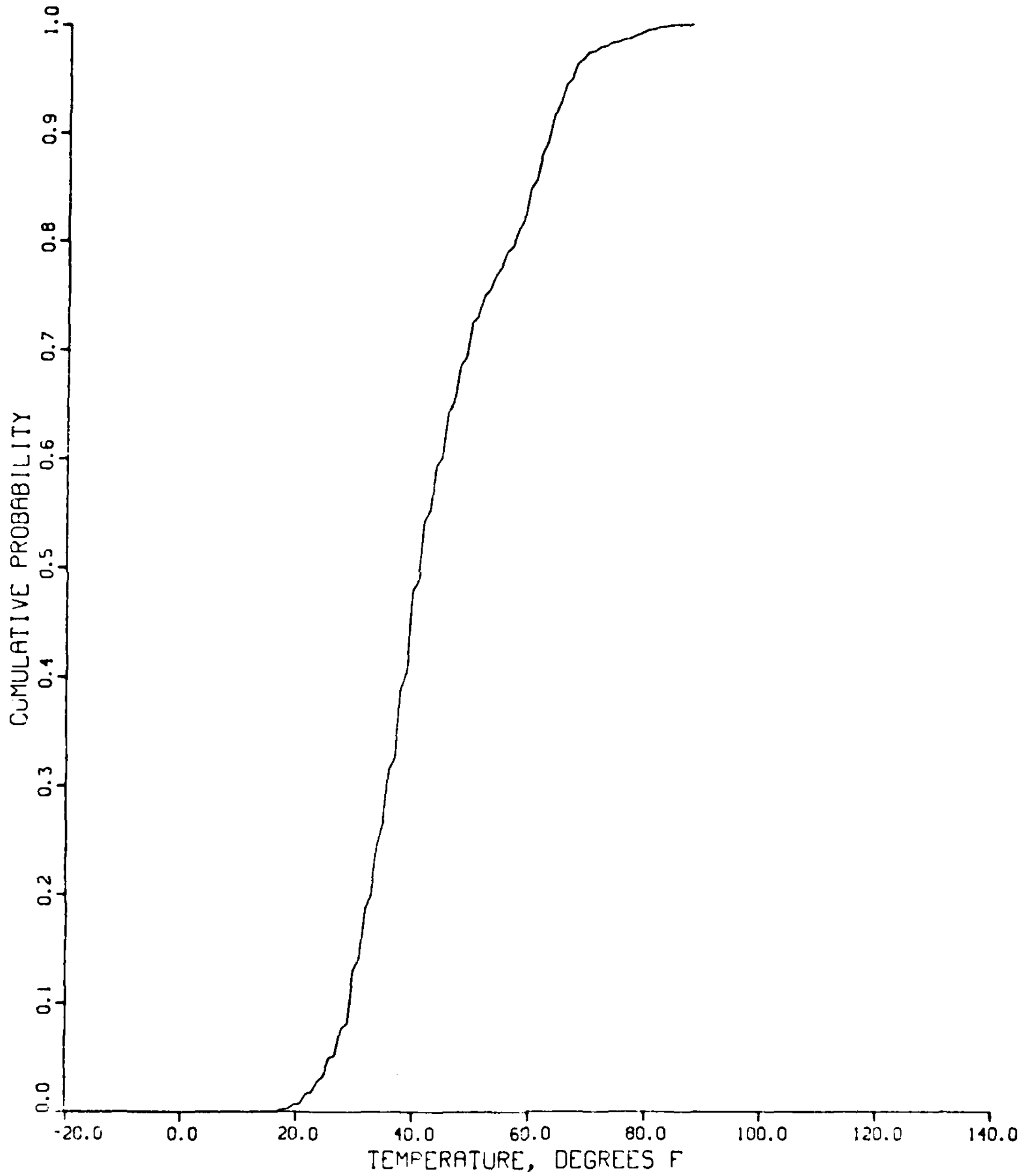

FIGURE C-20. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Brunswick, Maine.

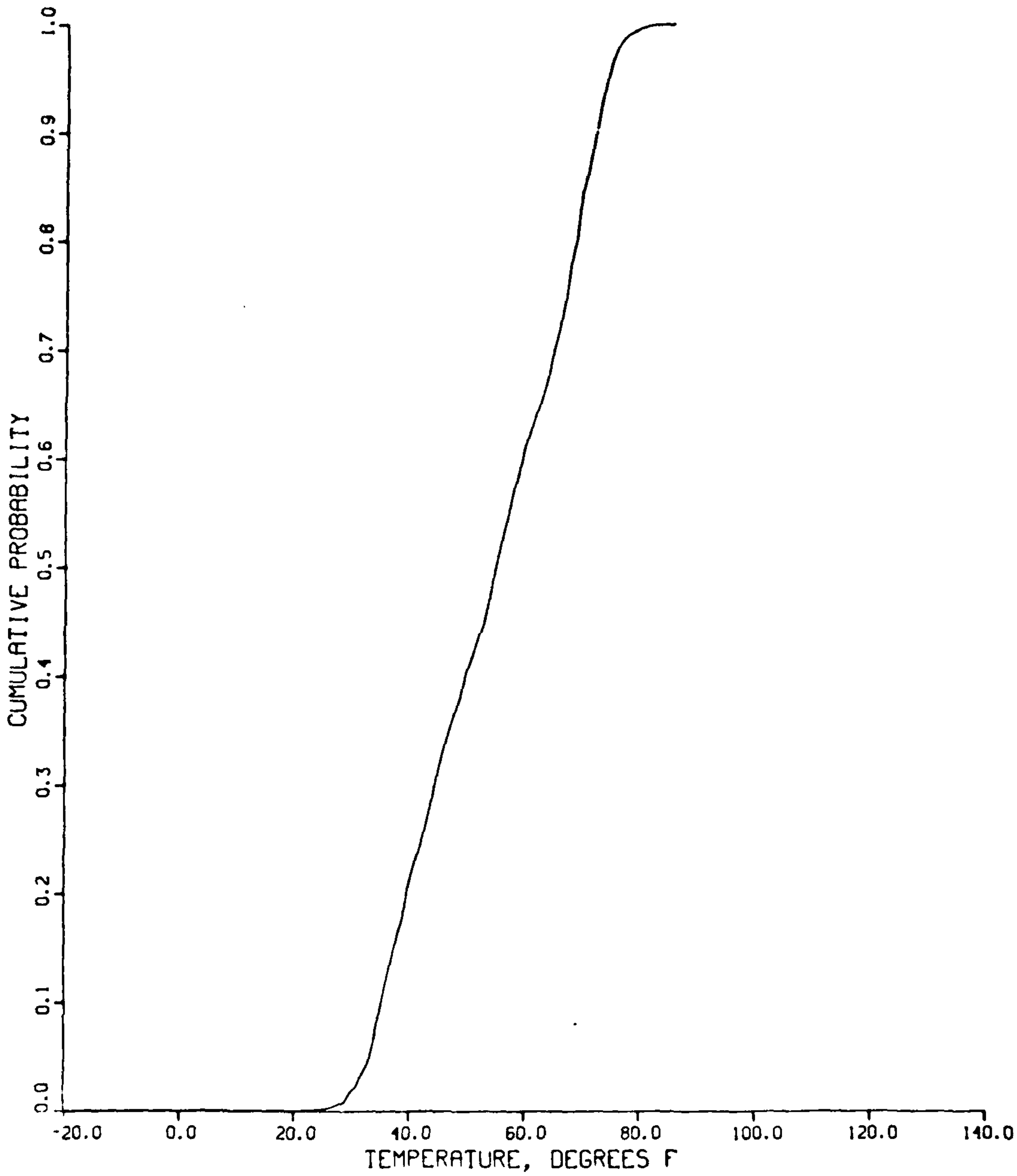

FIGURE C-21. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Crane, Indiana.

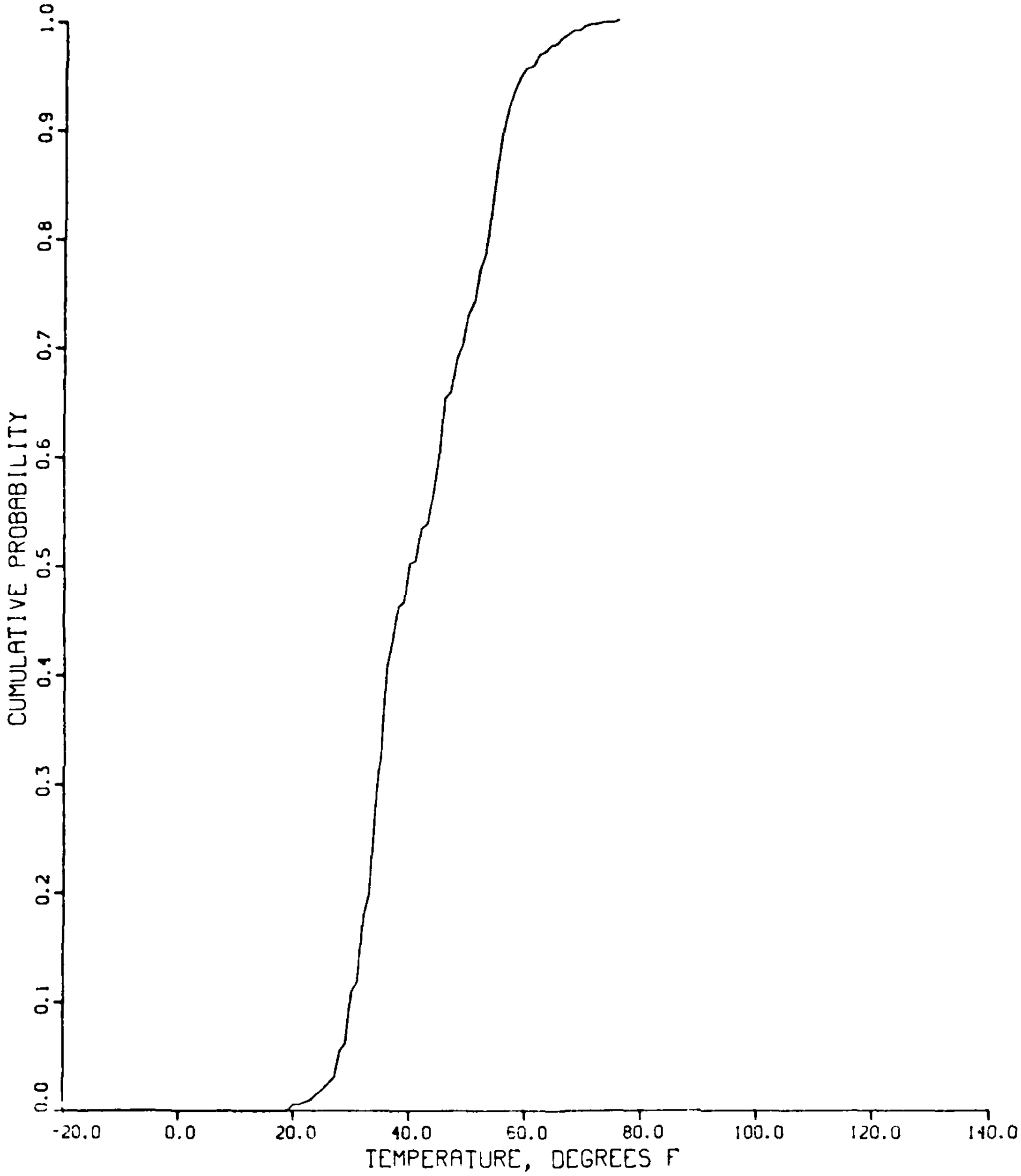

FIGURE C-22. Igloos -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Kodiak, Alaska.

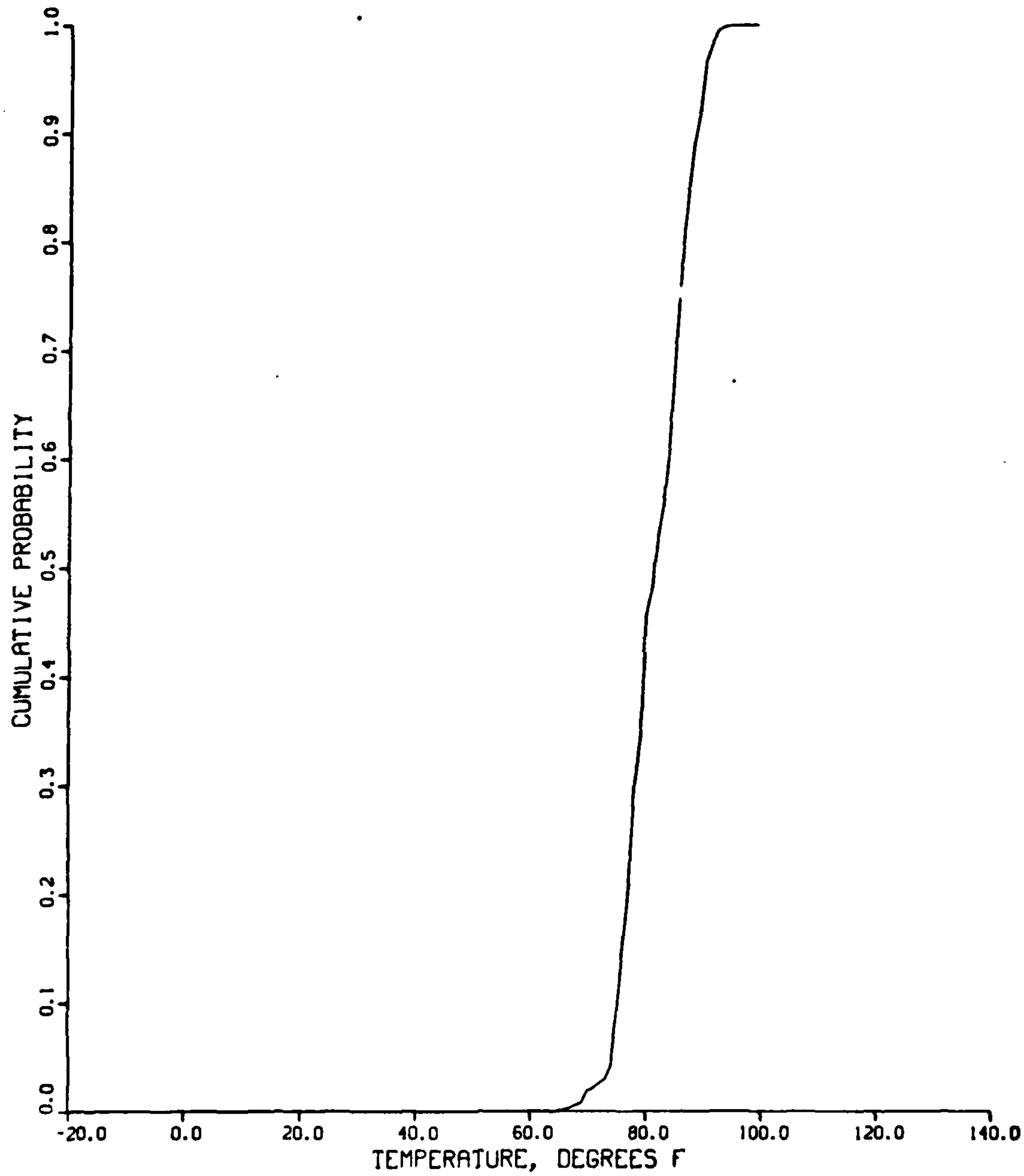

FIGURE C-23. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Agana, Guam.

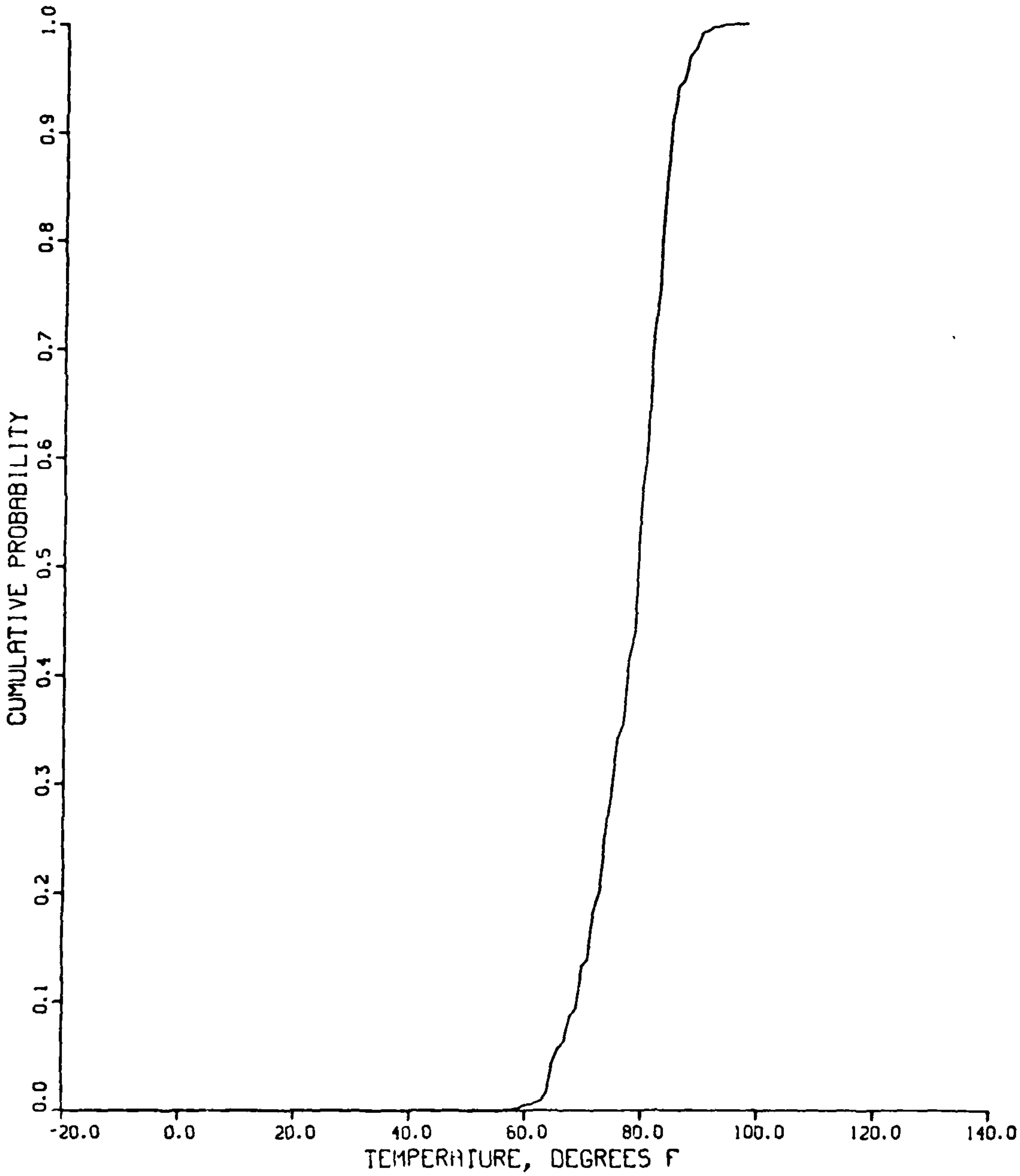

FIGURE C-24. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Guantanamo Bay, Cuba.

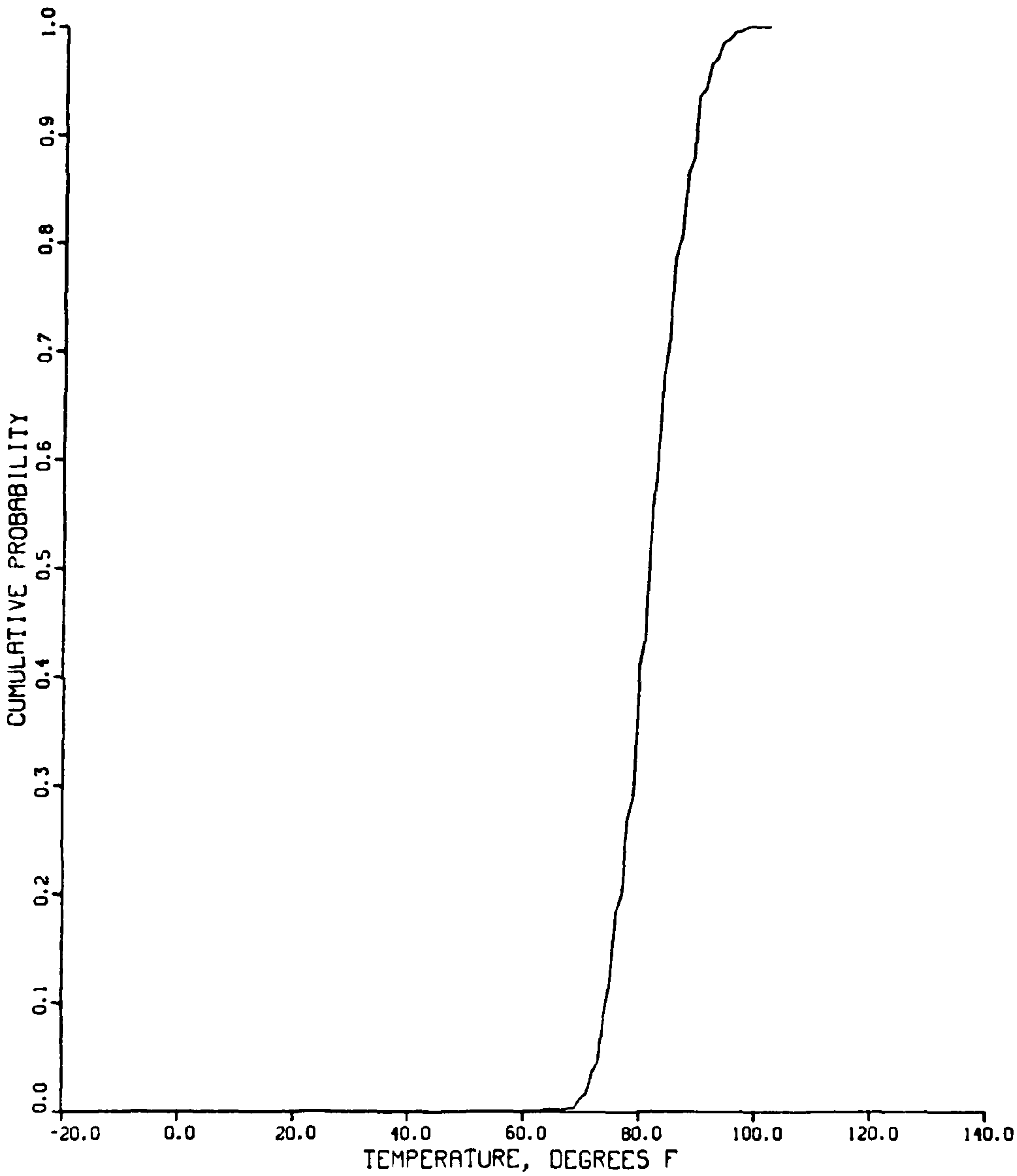

FIGURE C-25. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Roosevelt Roads, Puerto Rico.

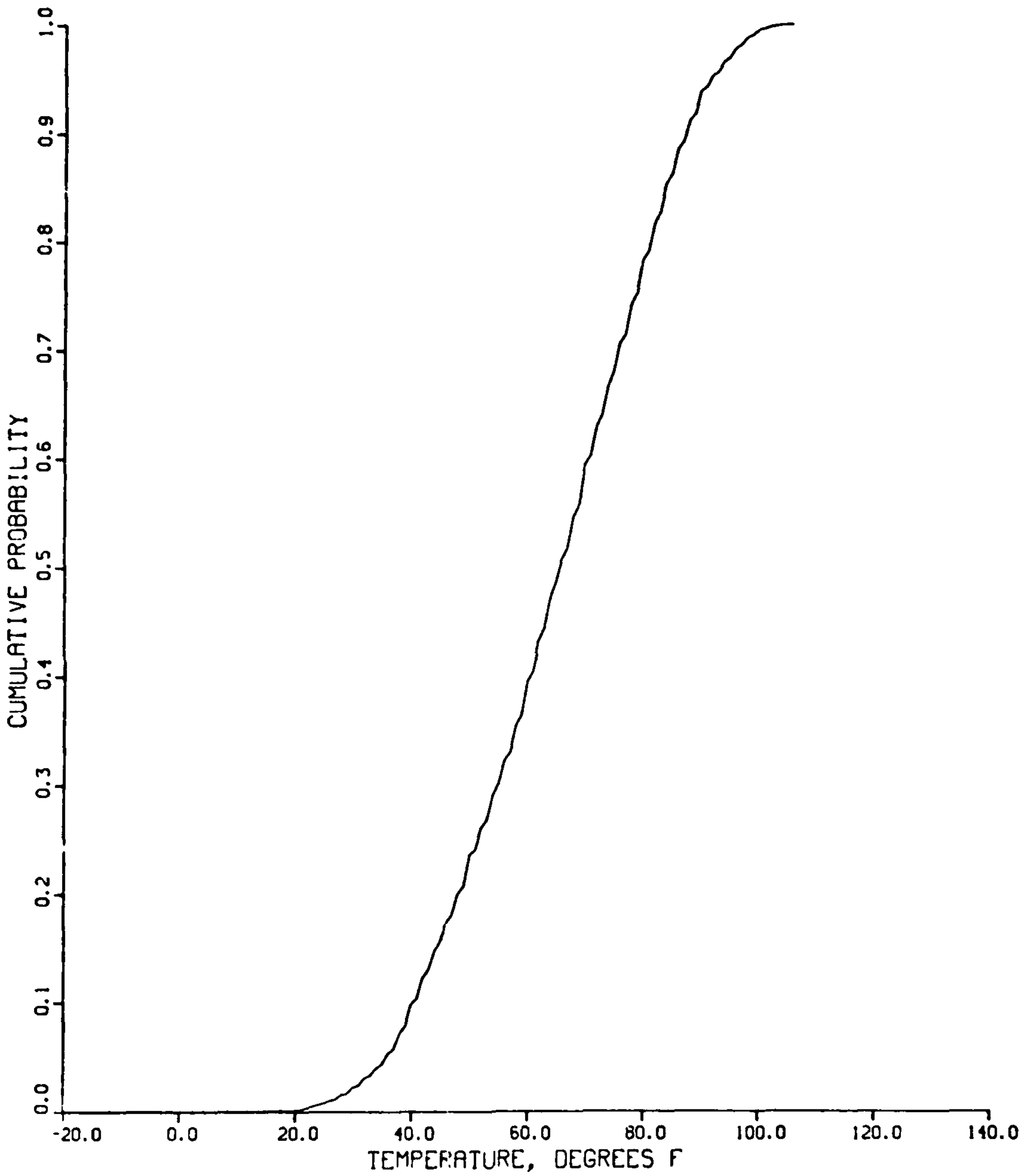

FIGURE C-26. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Dallas, Texas.

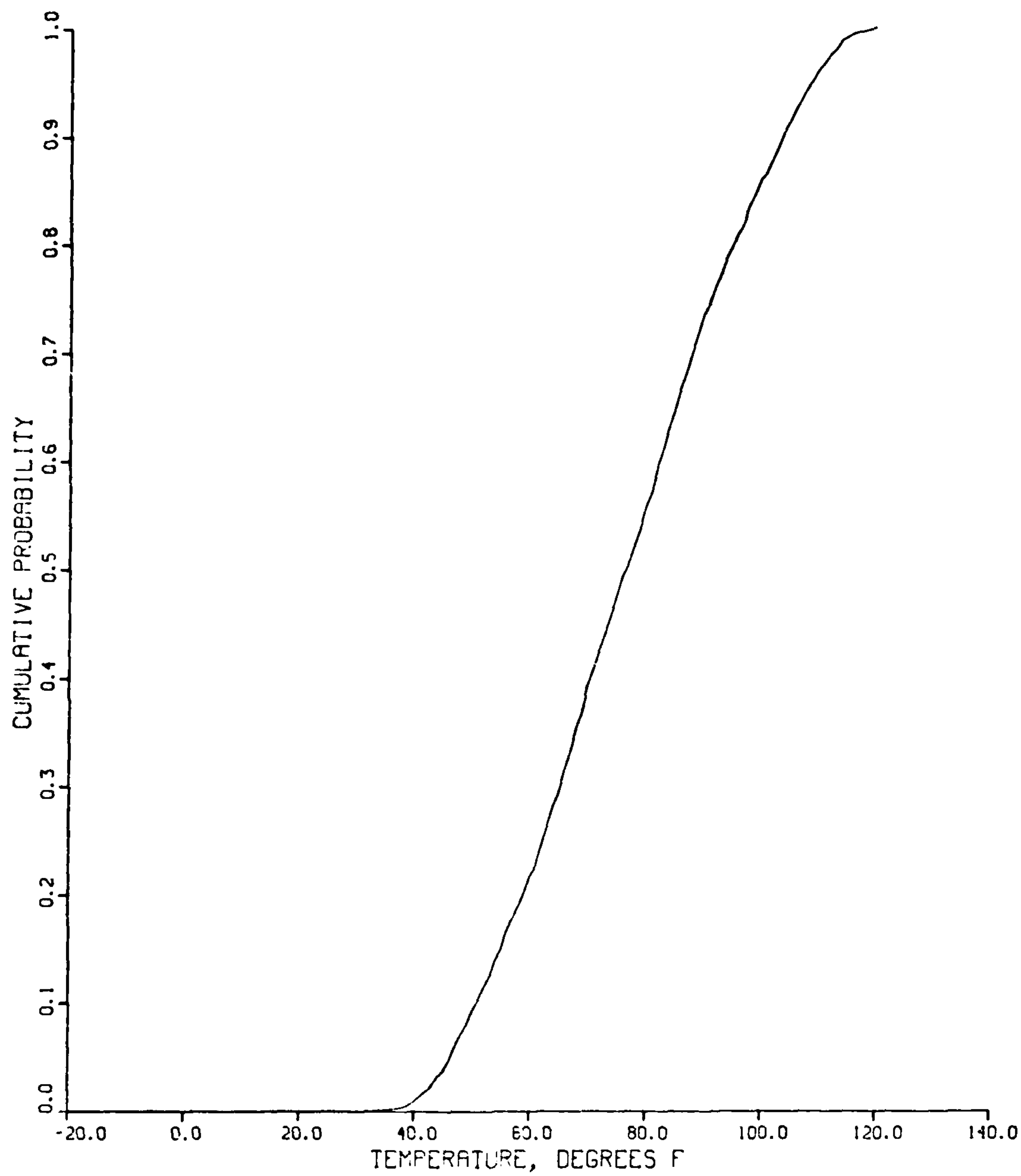

FIGURE C-27. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Yuma, Arizona.

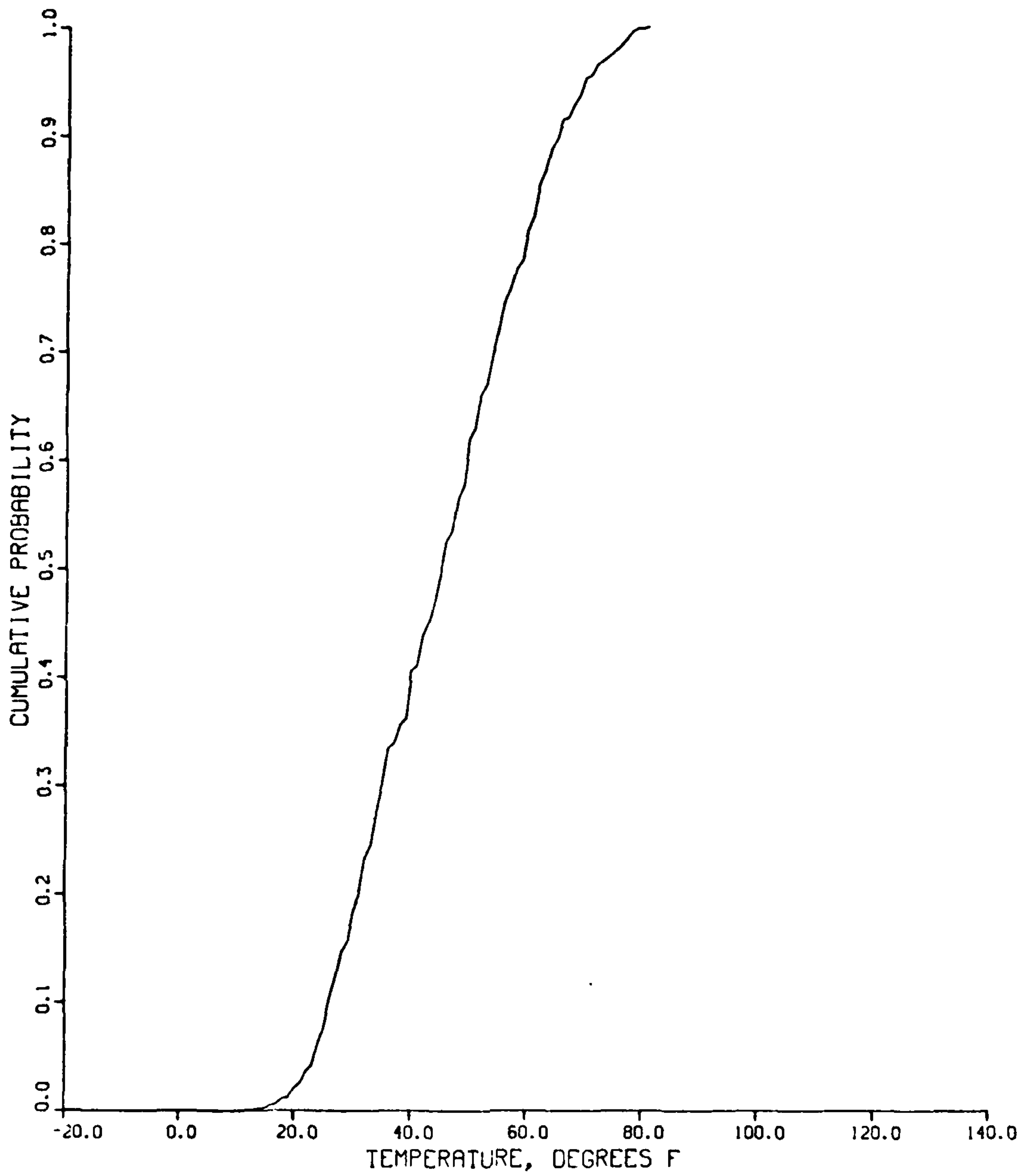

FIGURE C-28. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Kodiak, Alaska.

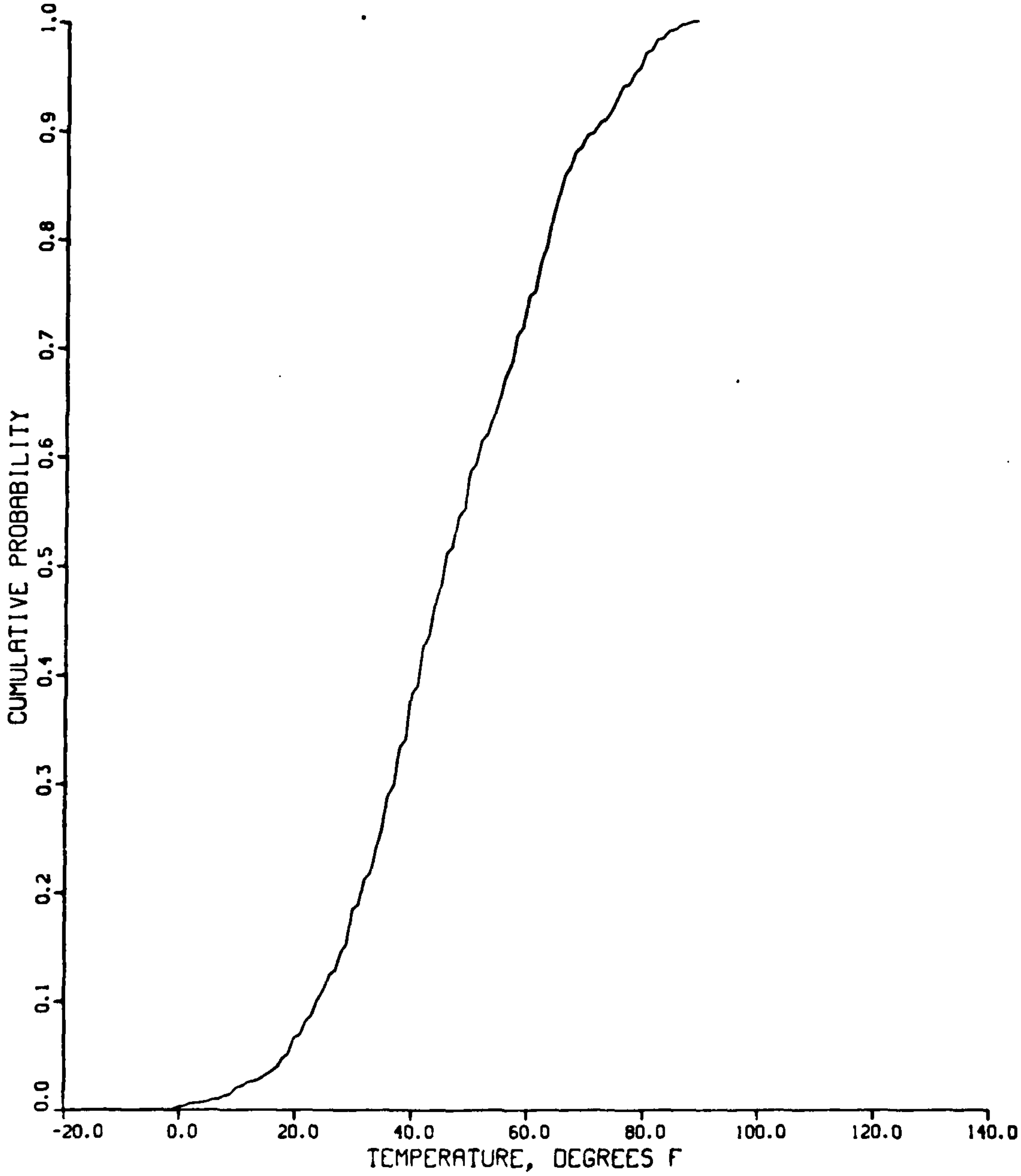

FIGURE C-29. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Brunswick, Maine.

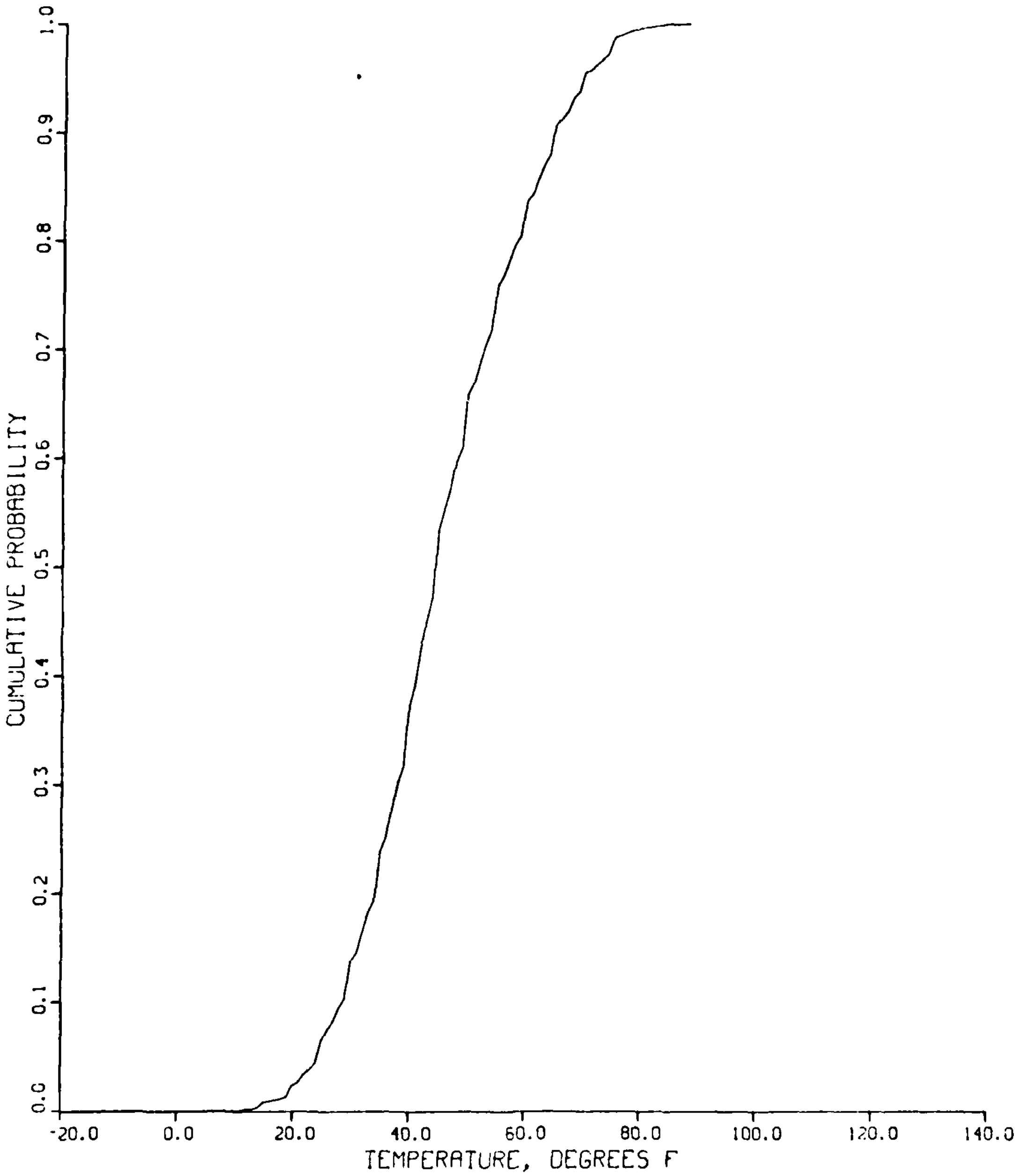

FIGURE C-30. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Adak, Alaska.

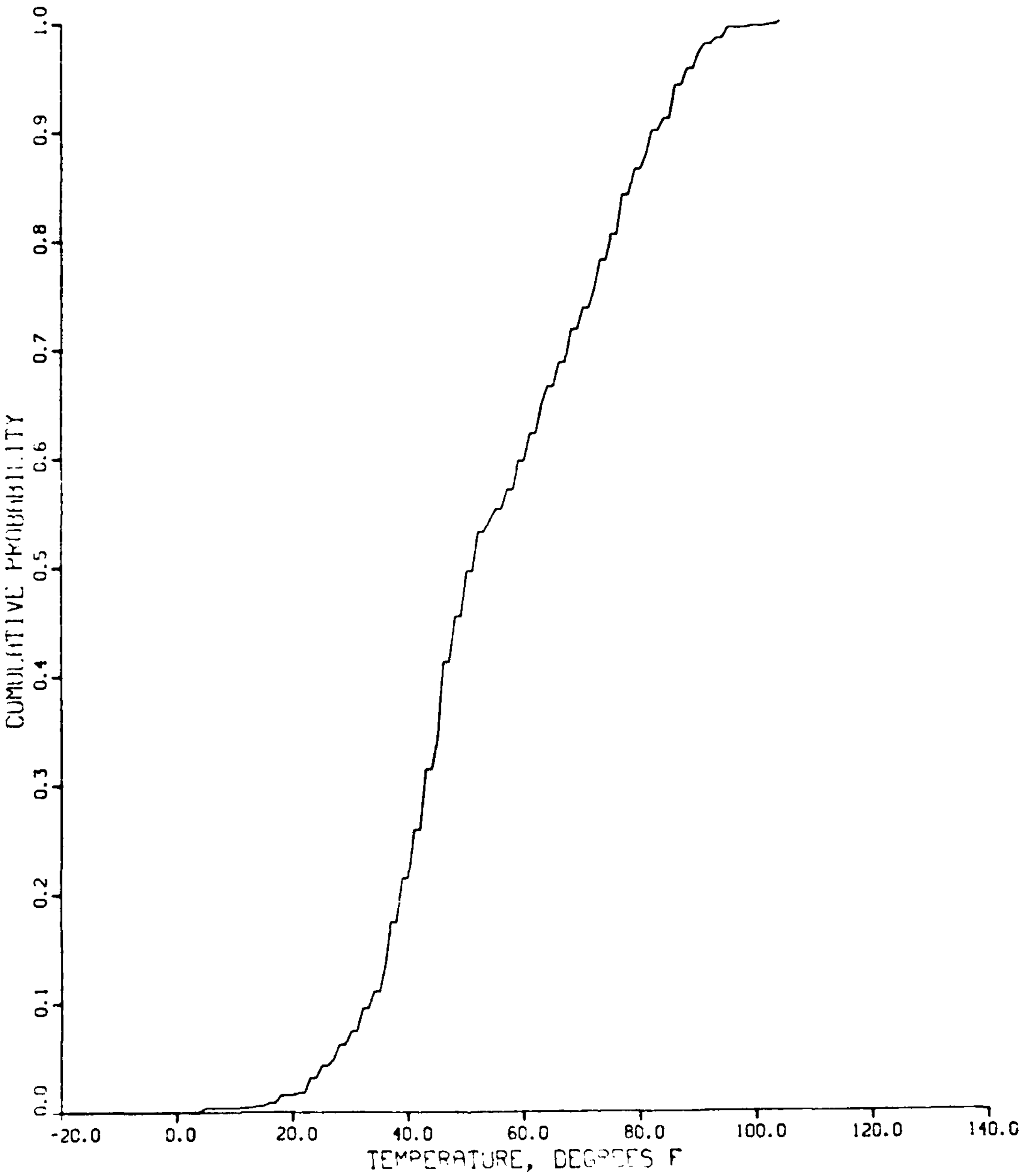

FIGURE C-31. Above-Ground Storehouse -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Wiesau, Germany.

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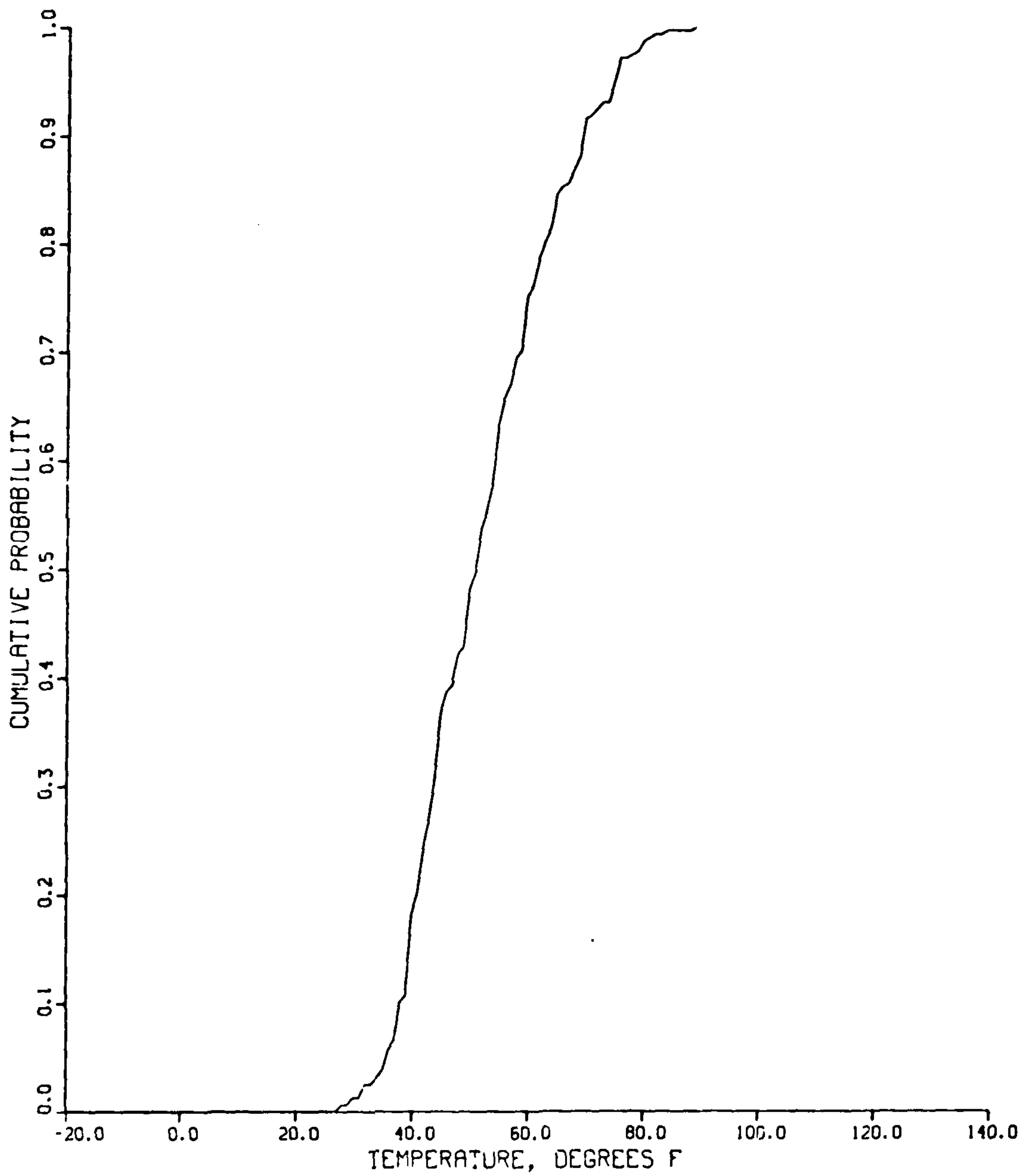

FIGURE C-32. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Seattle, Washington.

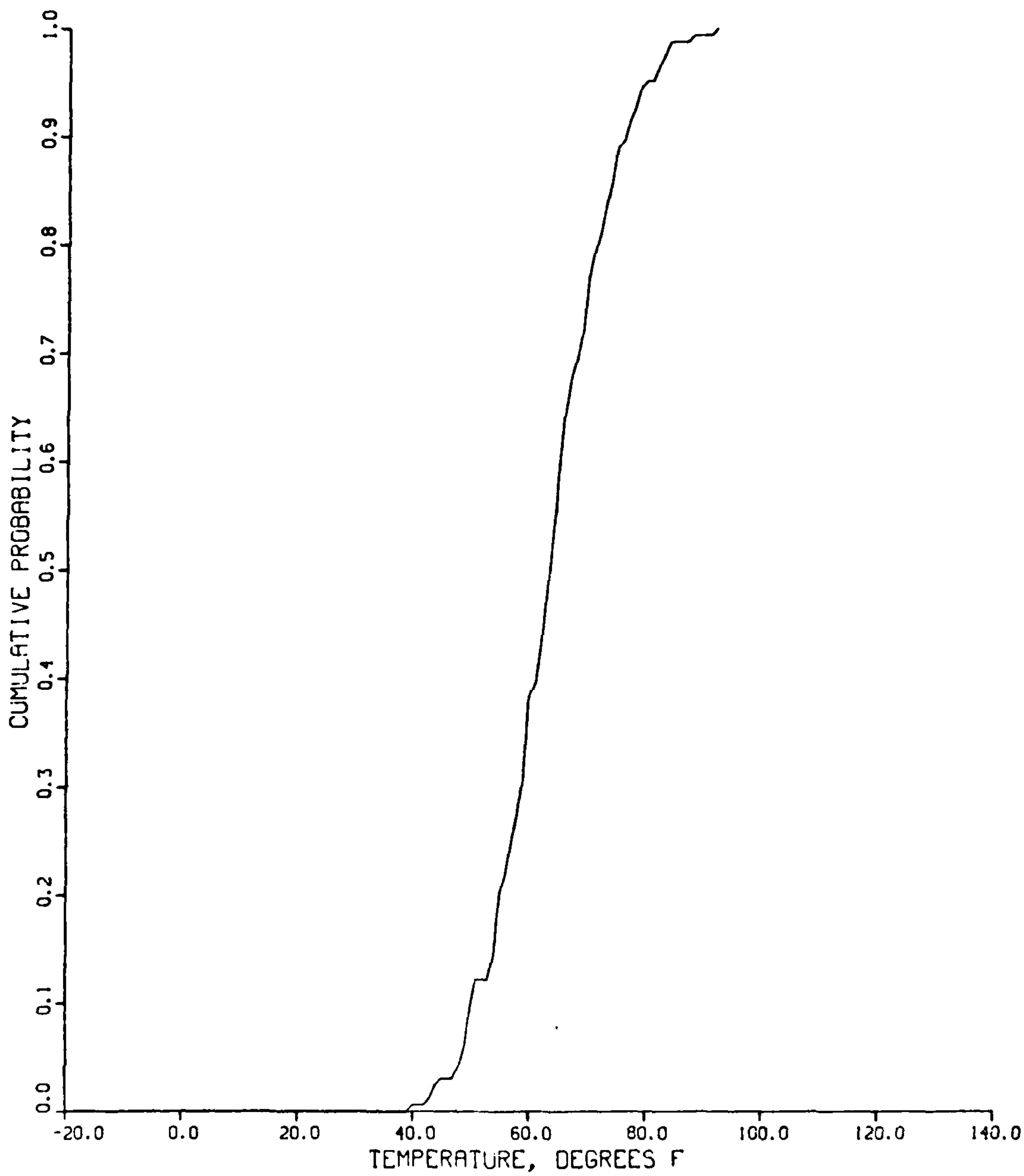

FIGURE C-33. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Seal Beach, California.

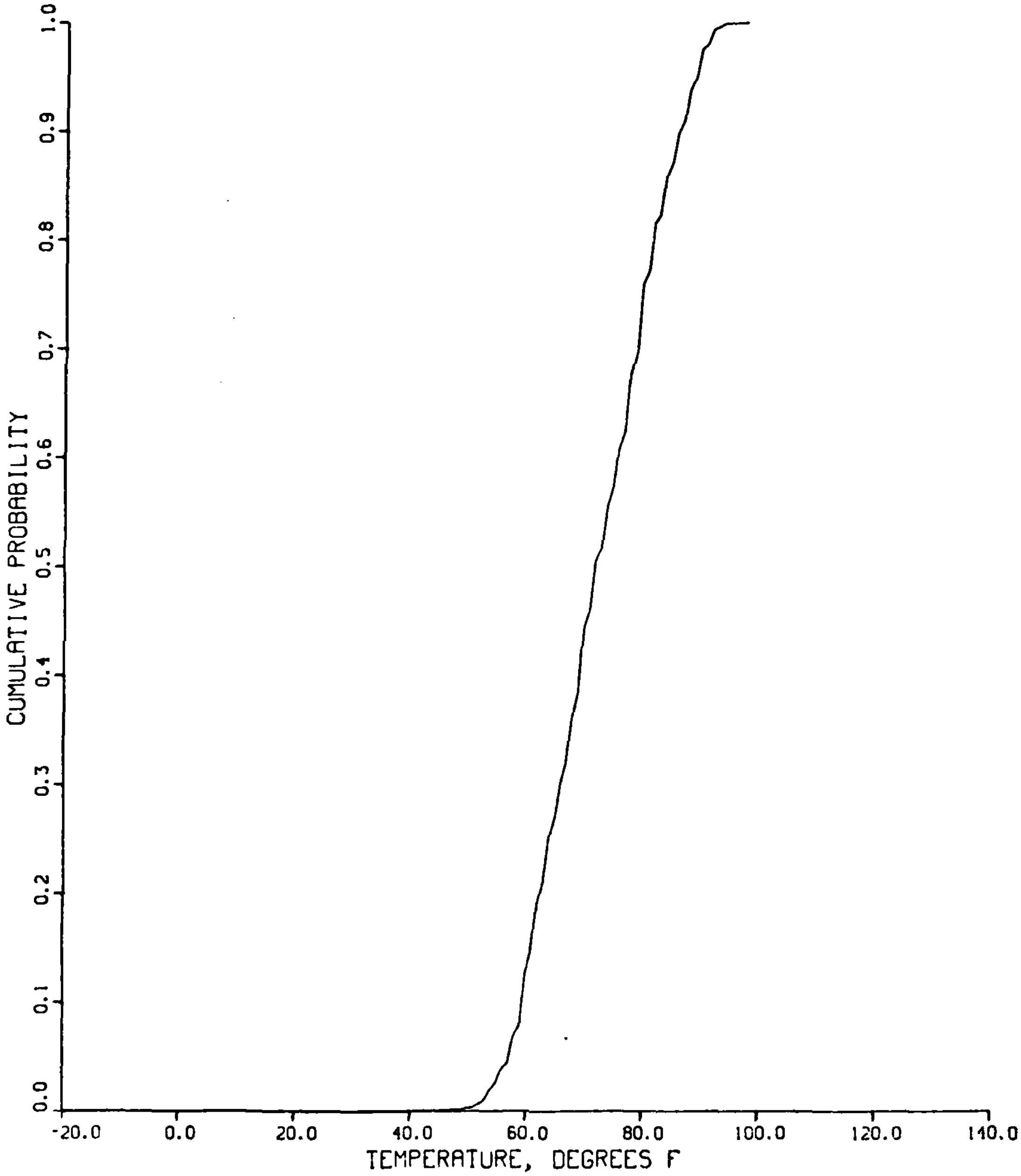

FIGURE C-34. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Naval Station, Bermuda.

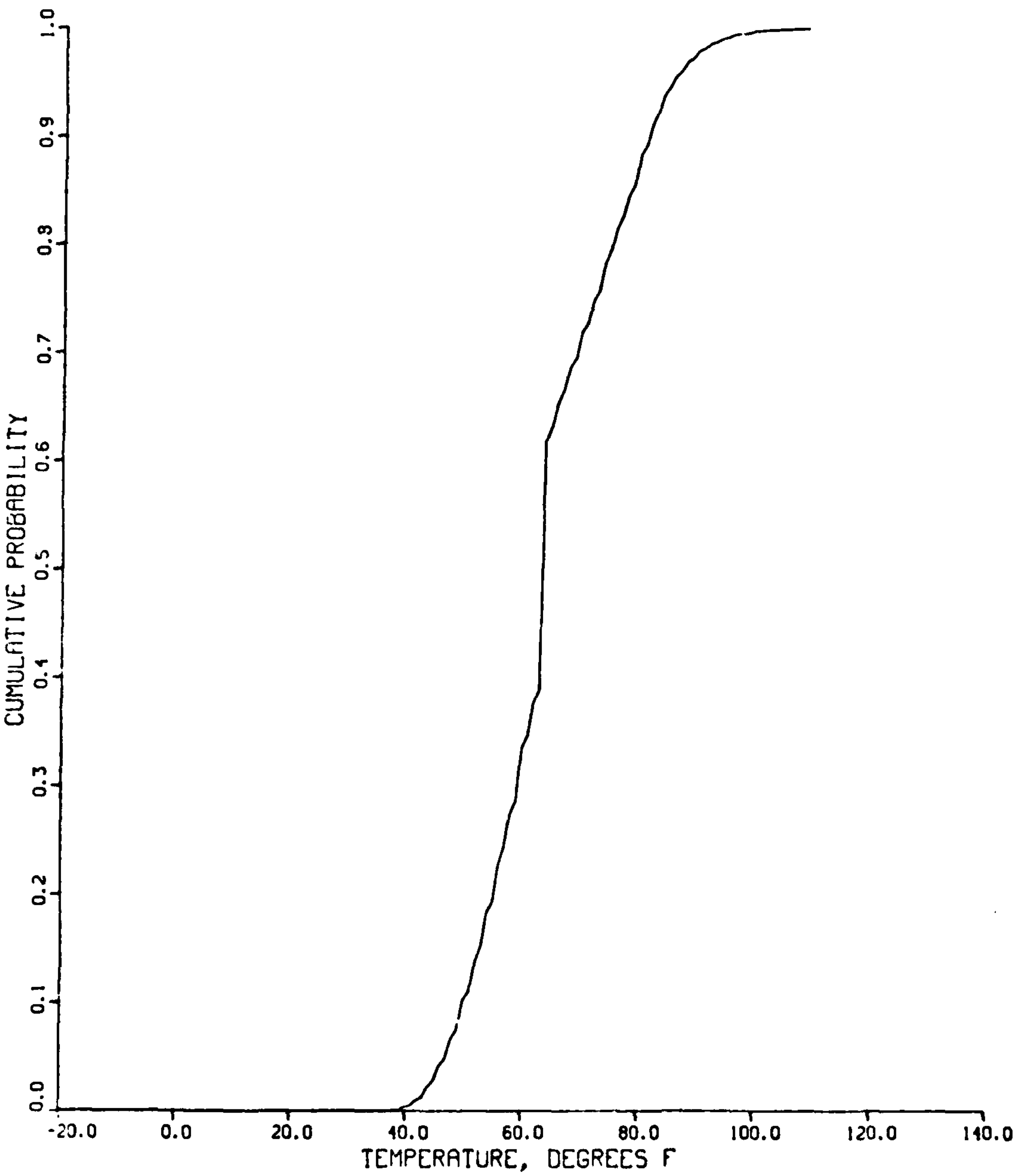

FIGURE C-35. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Messina, Sicily.

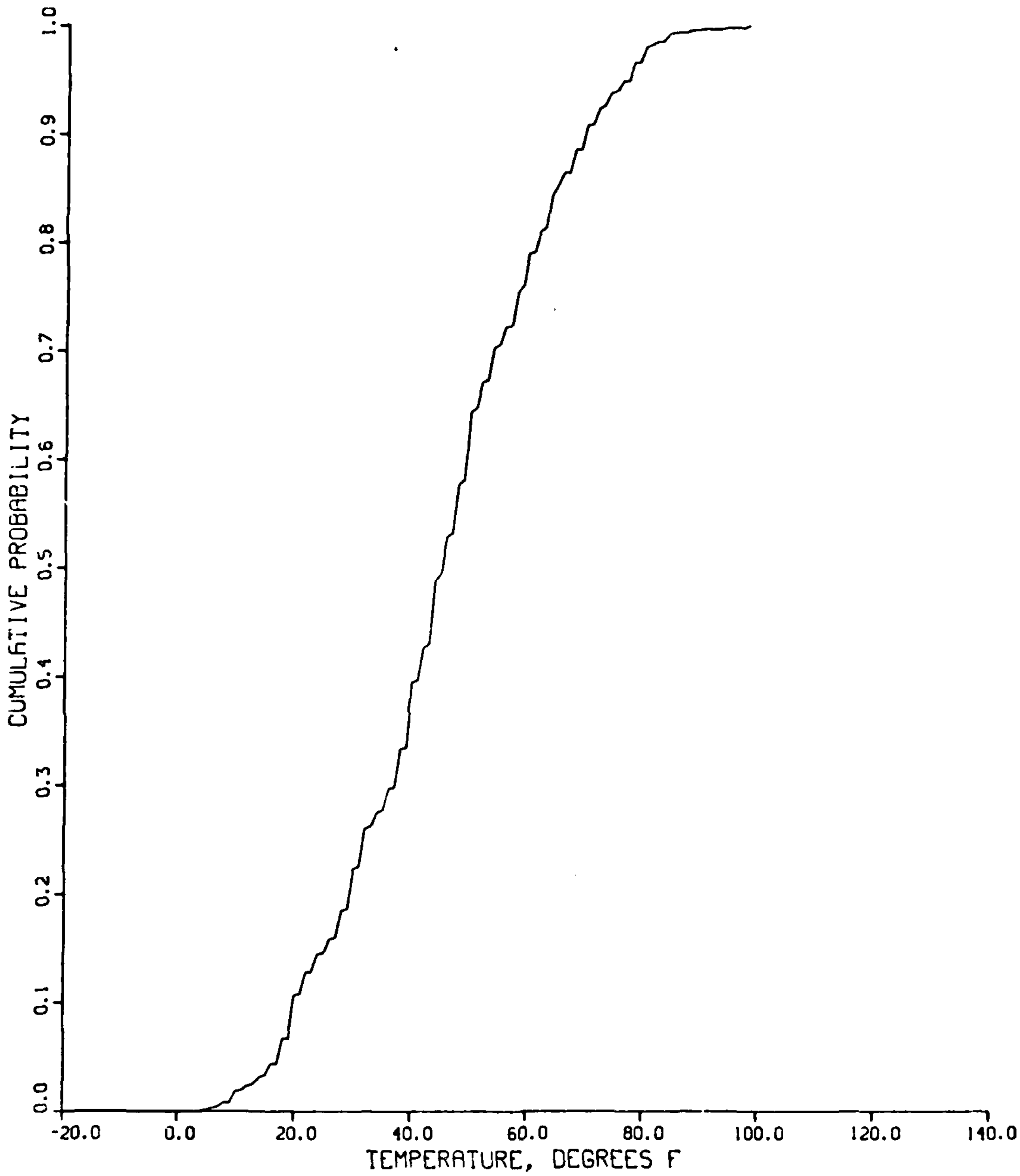

FIGURE C-36. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Keflavik, Iceland.

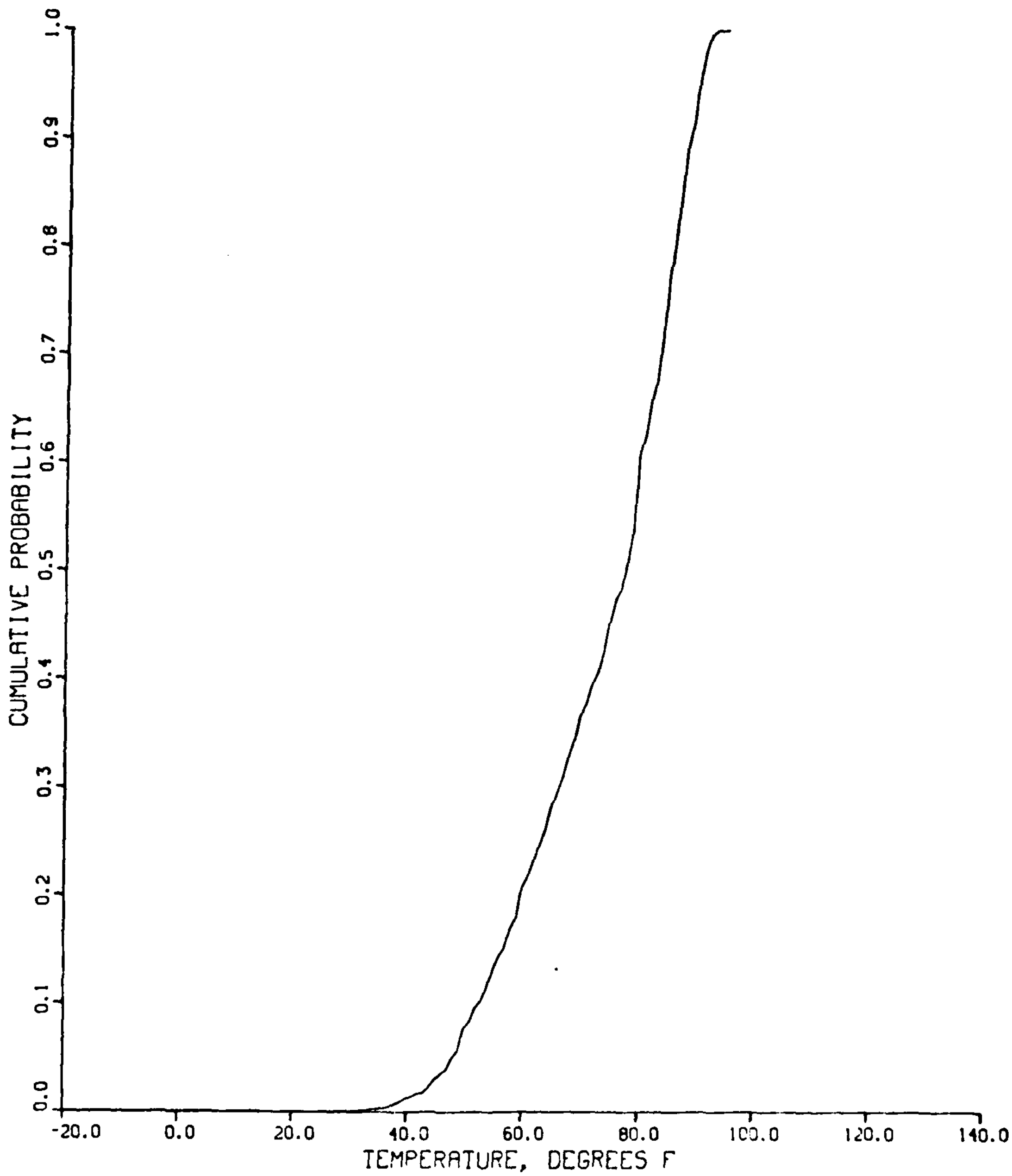

FIGURE C-37. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Corpus Christi, Texas.

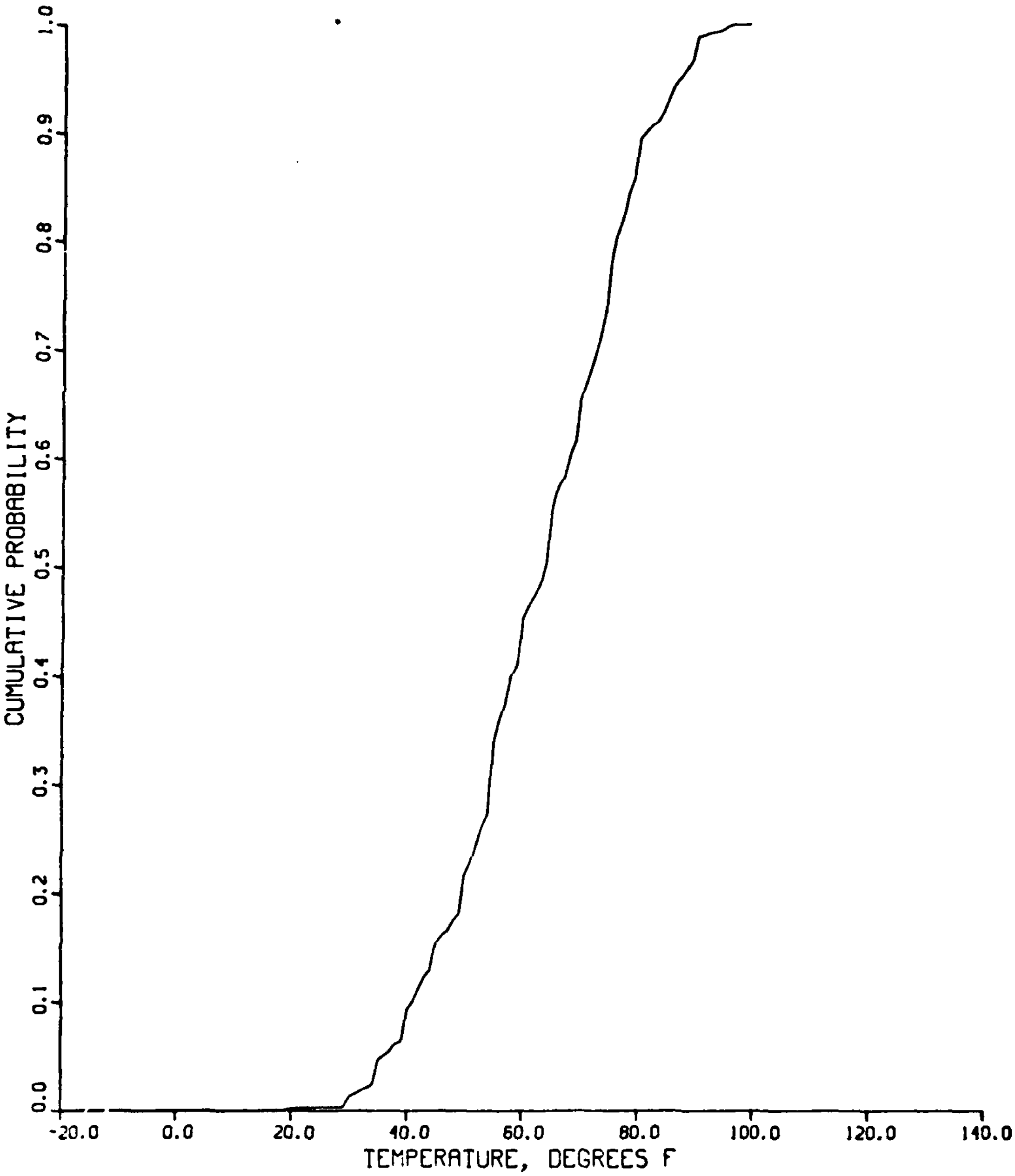

FIGURE C-38. Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Atsugi, Japan.

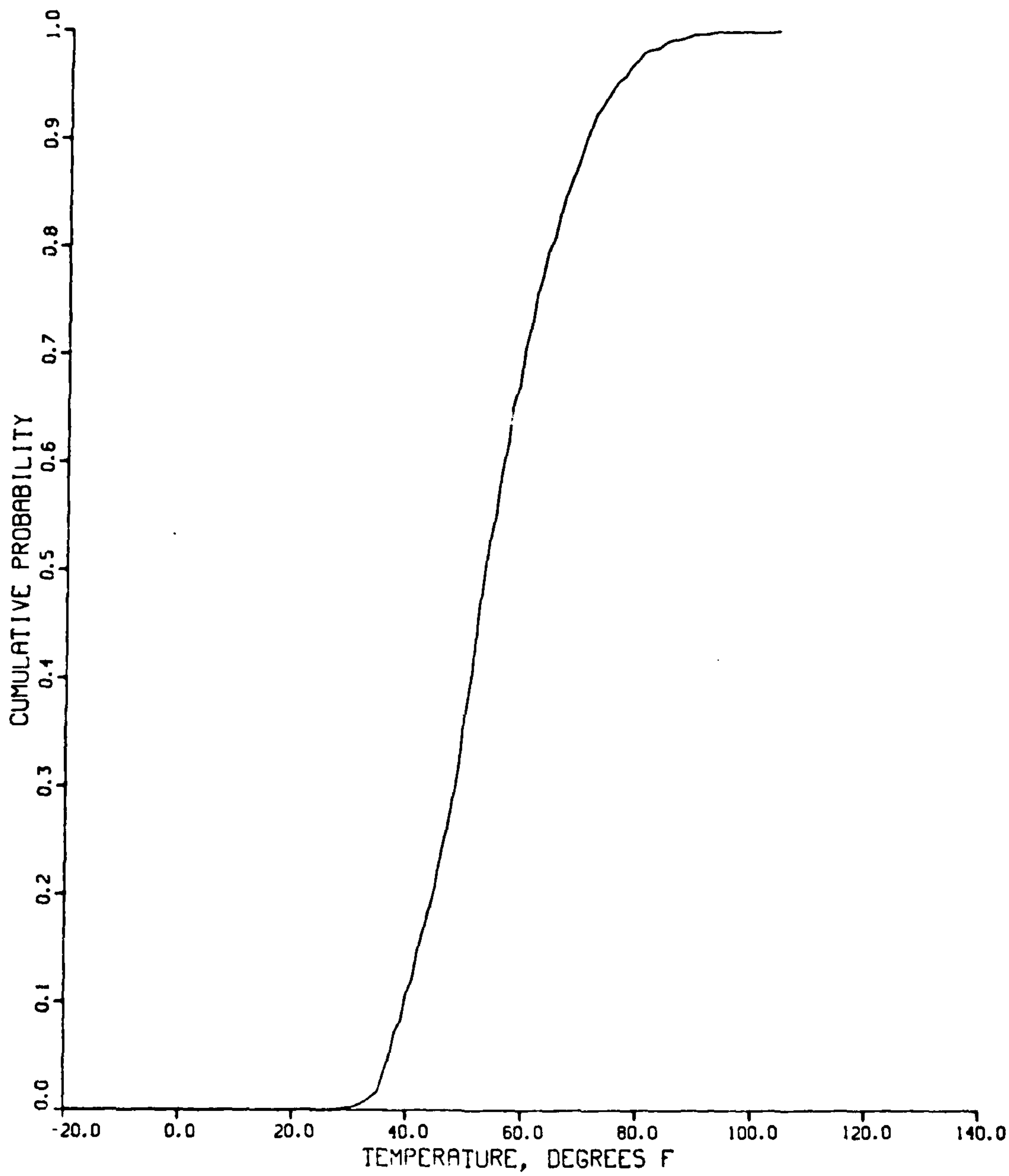

Figure C-39. Combined Igloos/Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- East Sale, Australia.

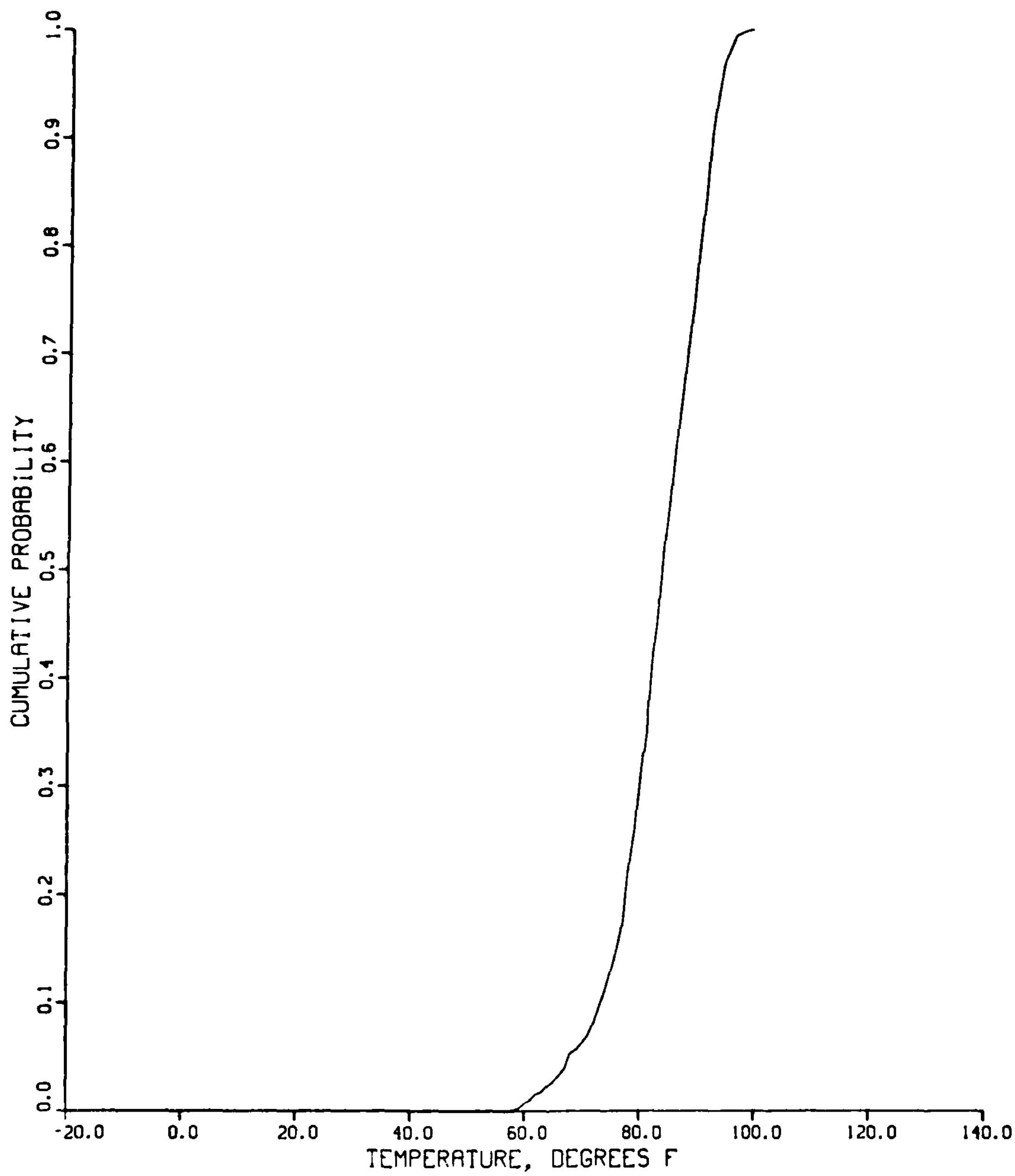

Figure C-40. Combined Igloos/Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Darwin, Australia.

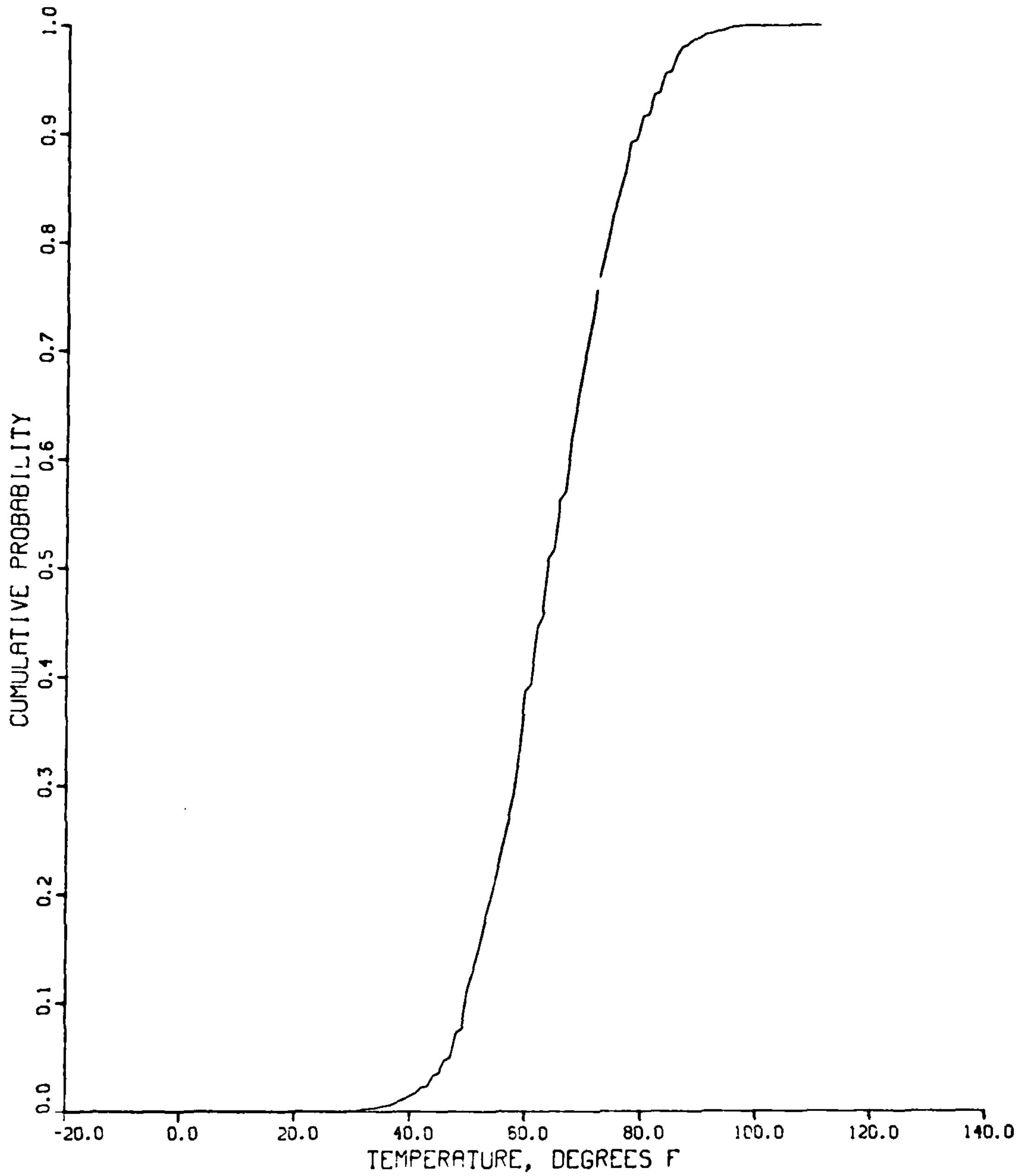

Figure C-41. Combined Igloos/Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Kingswood, Australia.

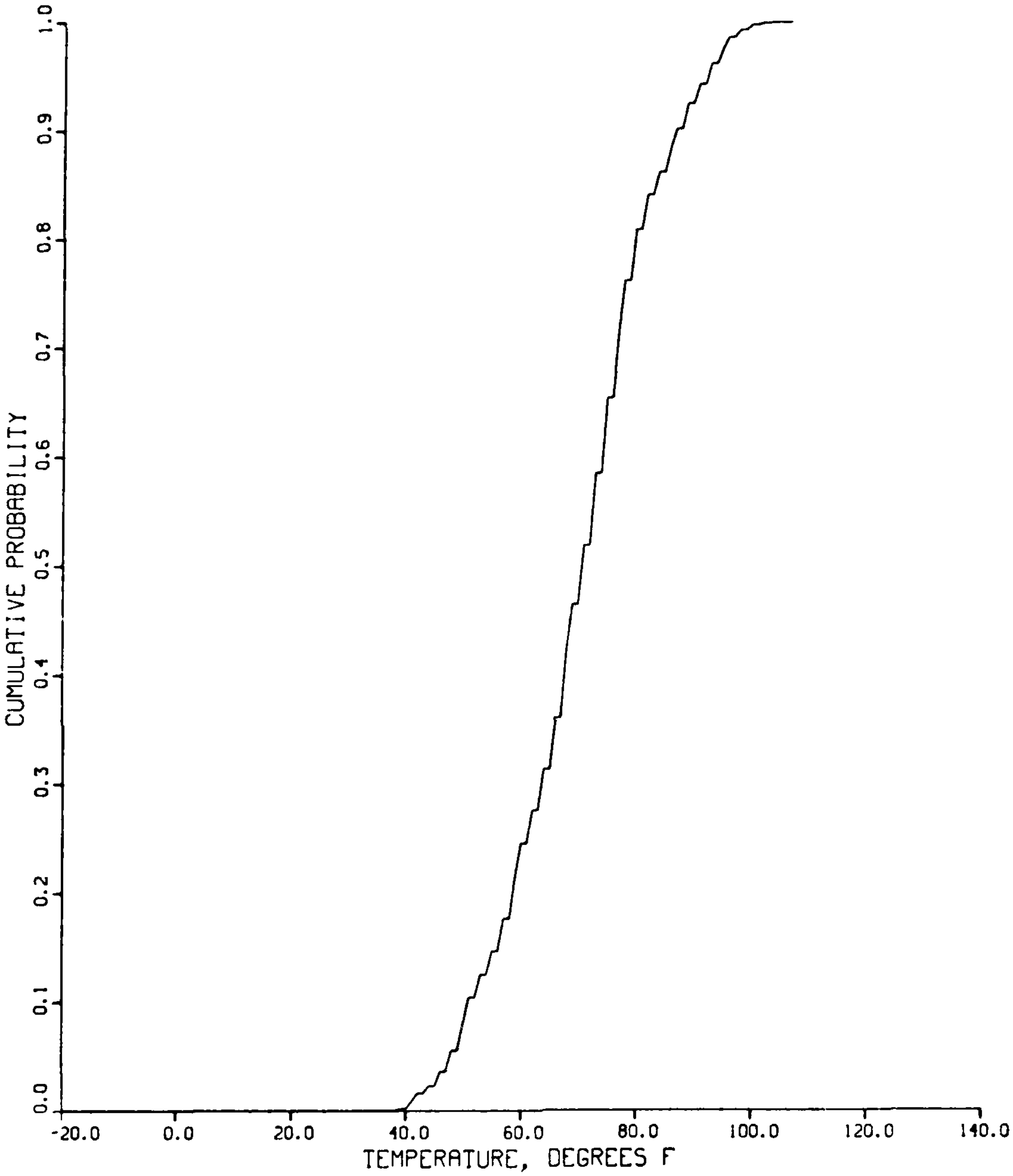

Figure C-42. Combined Igloos/Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- Amberly, Australia.

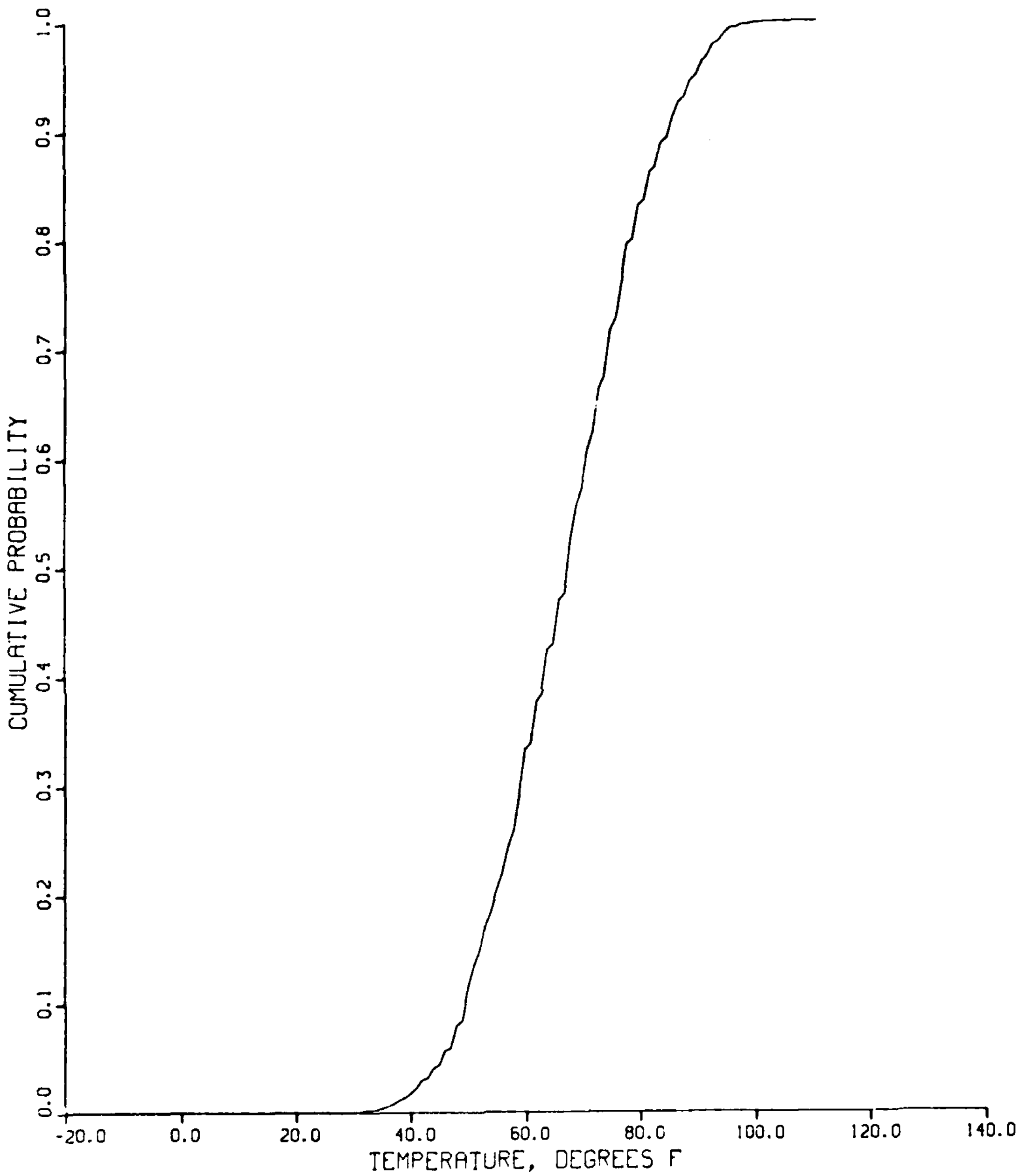

Figure C-43. Combined Igloos/Above-Ground Storehouses -- Cumulative Probability up to (TMIN and TMAX) Sub I -- All Australian Sites.

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JCM-00 (1)
JCM-02 (1)
JCM-06 (1)
JCM-40 (1)
JCM-A-00 (1)
JCM-A-40 (1)
JCM-G-00 (1)
JCM-G-40 (1)
JCM-M-40 (1)
JCM-S-00 (1)

14 Naval Electronic Systems Command

NAVELEX-00 (1)
NAVELEX-00B (1)
NAVELEX-03 (1)
NAVELEX-05 (1)
NAVELEX-470 (1)
NAVELEX-4702 (1)
NAVELEX-4703 (1)
NAVELEX-480 (1)
NAVELEX-520 (1)
NAVELEX-540 (1)
PME-107 (1)
PME-108 (1)
PME-117 (1)
PME-119 (1)

1 Naval Facilities Engineering Command (NFAC-03)
34 Naval Sea Systems Command
SEA-00 (1)
SEA-003 (1)
SEA-03D5 (1)
SEA-311 (1)
SEA-3133 (1)
SEA-322 (1)
SEA-61C (1)
SEA-61R (1)
SEA-62C (1)
SEA-62M2, G. Mustin (2)
SEA-62R (1)
SEA-62Y (1)
SEA-62YC (1)
SEA-62Y1 (1)
SEA-62Z (1)
SEA-62Z1 (1)
SEA-62Z2 (1)
SEA-62Z3 (1)
SEA-62Z4 (1)
SEA-62Z5 (1)
SEA-63Z (1)
SEA-64 (1)
SEA-90 (1)
SEA-90E (1)
SEA-90T (1)
SEA-902 (1)
SEA-94 (1)
SEA-99612 (2)
PMS-402 (1)
PMS-405 (1)
PMS-406 (1)
PMS-407 (1)
3 Chief of Naval Research, Arlington
ONR-100 (1)
ONR-200 (1)
Technical Library (1)
1 Assistant Secretary of the Navy (Research and Development)
2 Fleet Analysis Center, Naval Weapons Station, Seal Beach
Code 862, GIDEP Office (1)
Technical Library (1)
5 Naval Air Engineering Center, Lakehurst
Code 93 (1)
Code 9313
D. Broude (1)
Cornetz (1)
Technical Library (2)
2 Naval Air Test Center (CT-176), Patuxent River (Technical Library)
2 Naval Avionics Center, Indianapolis
R. D. Stone (1)
Technical Library (1)
1 Naval Ocean Systems Center, San Diego (Code 4473)
25 Naval Ordnance Station, Indian Head
Code 5A (1)
Code 5011C, A. P. Allen (1)
Code 5712A (1)
Code FS11C (1)
Code FS12A1 (1)
Code FS12A2 (1)
Code FS12A6 (1)
Code FS12B (1)
Code FS12D (1)
Code FS13 (1)
Code FS13A (1)
Code FS13C (1)
Code FS14 (1)
Code FS15A (1)
Code FS15B (1)
Code FS42 (1)
Code FS63 (1)
Code FS64 (1)
Code FS72 (1)
Code QA (1)
Code QA3 (1)
Code TDT, A. T. Camp (1)
J. Wiggin (1)
Technical Library (2)
1 Naval Postgraduate School, Monterey (Technical Library)
2 Naval Research Laboratory
Code 2600, Technical Library (1)
Code 5804, R. Volin (1)
1 Naval Ship Missile Systems Engineering Station, Port Hueneme

13 Naval Surface Weapons Center, Dahlgren
- Code D (1)
- Code T (1)
- Code TEE (1)
- Code TI (2)
- Code WXA, G. W. Allison (1)
- Code WXO (1)
- Code WXR (1)
- Code WXS (1)
- Code WXT (1)
- Code WXV (1)
- Jim Horten (1)
- Technical Library (1)

9 Naval Surface Weapons Center Detachment, White Oak Laboratory, Silver Spring
- Code 702
  - C. V. Vickers (1)
  - V. Yarow (1)
- Code KM (1)
- Code LX-1, Doyle (1)
- Code NO, French (1)
- Code WE (2)
- Code XWF, Parker (1)
- Technical Library (1)

1 Naval Underwater Systems Center, Newport

3 Naval Weapons Evaluation Facility, Kirtland Air Force Base
- APM-4, G. V. Binns (1)
- AT-2, J. L. Abbott (1)
- Technical Library (1)

2 Naval Weapons Quality Assurance Office, Washington Navy Yard
- Director (1)
- Technical Library (1)

4 Naval Weapons Station, Colts Neck
- Code 70, C. P. Troutman (1)
- Naval Weapons Handling Center
  - Code 805, R. E. Seely (1)
- Technical Library (2)

1 Naval Weapons Station, Concord (Technical Library)

5 Naval Weapons Station, Seal Beach
- Code QESX (1)
- Code QESX-3 (1)
- Environmental Test Branch (1)
- QE Department (1)
- Technical Library (1)

2 Naval Weapons Station, Yorktown
- Code 3032, Smith (1)
- Technical Library (1)

7 Naval Weapons Support Center, Crane
- Code 30331, Lawson (1)
- Code QETE (1)
- Code RD (1)
- NAPEC, J. R. Stokinger (1)
- S. Strong (2)
- Technical Library (1)

8 Pacific Missile Test Center, Point Mugu
- Code 1141, T. Elliott (1)
- Code 1143, C. V. Ryden (1)
- Code 1202, L. Matthews (1)
- Code 2133, F. J. Brennan (1)
- Code 2143, R. W. Villers (1)
- Code 3322, E. P. Olsen (1)
- Code 6872, Technical Library (1)
- Code 7379, Sparrow Office (1)

1 Army Armament Research and Development Command, Dover (DRDAR-TSS)

1 Army Training & Doctrine Command, Fort Monroe (ATCD-T)

7 Aberdeen Proving Ground
- AMSTE-TA
  - Goddard (1)
  - Peterson (1)
- DRSTE-AD-M, H. Eggbert (3)
- STEAP-MT-M, J. A. Feroli (1)
- Technical Library (1)

4 Army Engineer Topographic Laboratories, Fort Belvoir
- ETL-GS-EA (1)
- ETL-GS-EC, T. Neidringhaus (2)
- Technical Library (1)

2 Chemical Systems Laboratory, Aberdeen Proving Ground
- Research and Development Laboratory (1)
- Warfare Laboratory (1)

4 Harry Diamond Laboratories, Adelphi
- Technical Director (1)
- R. Hoff (1)
- R. Smith (1)
- Technical Library (1)

2 Office Chief of Research and Development
- Dr. Leo Alpert (1)
- Technical Library (1)

15 Headquarters, U.S. Air Force
- AF/CVB(S) (1)
- AF/SA (1)
- AF/SAG (1)
- AF/RD (1)
- AF/RDC (1)
- AF/RDPS, Allen Eaffy (1)
- AF/RST (1)
- AF/XO (1)
- AS/DASJL (1)
- ASCC/MC (1)
- CCN (1)
- RDQF (1)
- SAFAL (1)
- XOORC (1)
- XOORE (1)

1 Air Force Logistics Command, Wright-Patterson Air Force Base (Technical Library)

1 Air Force Systems Command, Andrews Air Force Base (Technical Library)

1 Strategic Air Command, Offutt Air Force Base (Technical Library)

1 Tactical Air Command, Langley Air Force Base (Technical Library)

1 Air Force Acquisition Logistics Division, Wright-Patterson Air Force Base (Technical Library)